ERIODICAL
1(1)

Volume 1, No. 1
New Series

March 1953

LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS
SEP 8 1953

# RECORDS OF OCEANOGRAPHIC WORKS IN JAPAN

Being the continuation of the
RECORDS OF OCEANOGRAPHIC WORKS IN JAPAN, Vol. 12, No. 2

Compiled by
SPECIAL COMMITTEE ON MARINE RESOURCES
in the
UNESCO COMMITTEE OF SCIENCE COUNCIL OF JAPAN

Published by
Japanese National Commission for Unesco

## BOARD OF EDITORS

**Editor-in-Chief**

Masayoshi Ishibashi
Faculty of Science, Kyoto University

**Associate Editors**

Yoshio Hiyama
Yasuo Miyake
Mahito Nakano
Michitaka Uda

**Editors**

(Physical Oceanography)
Koji Fukutomi
Shoichiro Hayami
Koji Hidaka
Mahito Nakano
Kanji Suda
Ryutaro Takahashi
Kiyoo Wadachi

(Biological Oceanography)
Shinkishi Hatai
Denzaburo Miyaji
Yo Okada
Yukio Yamada

(Geological Oceanography)
Masao Hanzawa
Hiroshi Niino

(Chemical Ocenography)
Masayoshi Ishibashi
Yasuo Matsudaira
Yasuo Miyake

(Fisheries)
Hiroaki Aikawa
Motosaku Fujinaga
Yoshio Hiyama
Takeo Imai


## SUGGESTIONS TO AUTHORS OF PAPERS FOR THE RECORDS OF OCEANOGRAPHIC WORKS IN JAPAN

An author wishing to contribute a paper to the RECORDS OF OCEANOGRAPHIC WORKS IN JAPAN should submit in compliance with the following suggestions:

1. Manuscripts will be accepted within the scope of
   Physical oceanography
   Geological oceanography
   Chemical oceanography
   Biological oceanography and
   Fisheries
2. An original and a copy of his manuscript, type-written, double-spaced on 21 x 29.5 cm paper, within 12 sheets, which should make 6 printed pages including plates and tables.
3. The manuscript should be addressed to the competent editor and mailed to the official in charge of the Special Committee on Marine Resources in the Unesco Committee of Science Council of Japan, Ueno Park, Tokyo, Japan.
4. Follow this Publication for forms of headings and references, etc.
5. The editors reserve the right to accept the manuscripts and to make minor editorial changes in them, so all papers may conform to the over-all style of this publication.

# PREFACE

*Records of Oceanographic Works in Japan*, a journal devoted to the development of oceanography, was issued in March 1928 and continued until its Volume 12, No. 2, March 1941, when it was suspended due to the World War II.

In October 1951, the Science Council of Japan resolved at its general conference to organize a Unesco Committee and at the same time a Special Committee on Marine Resources was established as one of its sub-committees.

In the same year, Japan became a member of Unesco through the resolution passed at the sixth general conference in Paris. At the seventh general conference November 1952 in Paris, the Japanese delegates made a proposal to revive the programme concerning oceanographic research for the improvement of the living conditions of mankind and this proposal was approved by the conference.

In the meantime, the Natural Science Committee of the Japanese National Commission for Unesco at its first meeting held in October 1952 resolved to the effect that its activities should be concentrated upon the development of marine resources. Subsequently close cooperation was established between this Committee and the Special Committee on Marine Resources of the Science Council of Japan. This resulted in the revival of the long-suspended *Records of Oceanographic Works in Japan*, this time, its publisher being the Japanese National Commission for Unesco.

It is sincerely hoped that this publication will continue and make available to the world many worthy papers on oceanography both in its pure and applied fields with the anticipation that it may contribute at the same time to the development of the vast marine resources.

March 1953

Masayoshi ISHIBASHI

Professor of Kyoto University,
Member of the Japanese National Commission for Unesco
and
Chairman of the Special Committee on Marine Resources,
Unesco Committee, Science Council of Japan.

# CONTENTS


Currents of Kuroshio and its branches in the seas adjacent to Hachijo Island in relation with fisheries (Report I).....M. Uda... 1

On the Cauchy-Poisson waves caused by eruption of a submarine volcano. ..... S. Unoki and M. Nakano... 11

On the eddy diffusion of pumices ejected from Myojin reef in the Southern Sea of Japan. .....M. Hanzawa... 18

On the variation of the oceanic condition in the sea near the fixed point "Extra". ..... J. Fukuoka and T. Tsuiki... 23

On the circulations of currents in the China Eastern Sea.....Z. Yasui and M. Matsuno... 28

On the annual variation in oceanographical elements at a fixed point (39 N, 153 E) in Pacific Ocean .....M. Koizumi... 36

A current meter using a phototube. .....T. Nan'niti... 44

"Kuroshio" undersea observation chamber. .....N. Inoue, T. Sasaki and R. Oaki... 52

On the effect of waves upon the vertical distribution of water temperatures.....T. Ichiye... 63

On the hydrographical conditions of the Sea of Japan in Spring and Summer 1949. ..... I. Yamanaka... 71

Preliminary report of the observations on ocean waves at the Hachijo Island. ..... K. Hidaka, K. Yoshida and K. Kajiura... 81

Studies on Minute elements in Sea-water. .....M. Ishibashi... 88

A study on the property of the coastal water around Hachijo Island. ..... Y. Miyake, Y. Sugiura and K. Kameda... 93

Notes on the ecology of a plankton copepod, *Labidocera pavo* Giesbrecht.....S. K. Wada... 100

Observations on some marine luminous organisms of Hachijo Island, Japan. ...Y. Haneda... 103

On some new or noteworthy algae from Hachijo Island.....Y. Yamada and S. Segawa... 109

Notes on the flying fishes of Hachijo Island, with nomenclatorial remarks of the flying fishes of the mainland of Japan and Hokkaido. I. "Tobi-uo" *Prognichthys agoo* ..... T. Abe... 115

Molluscan Fauna of Hachijo-jima (preliminary report) .....I. Taki... 124

The pelagic copepods of the Izu region..... O. Tanaka... 126

Personal differences and degree of difficulty in age determination of six fish species ..... Y. Hiyama... 138

Catches of a Japanese trawler in Saurashtra waters. .....K. R. Srivatsa... 149

# THE KUROSHIO AND ITS BRANCH CURRENTS IN THE SEAS ADJACENT TO HACHIJO ISLAND IN RELATION TO FISHERIES. (REPORT I)

M. UDA

THE TOKYO UNIVERSITY OF FISHERIES

The following report illustrates some of the results obtained in the cooperative biological and oceanographic researches in the waters adjacent to Hachijō Is. during the fiscal years 1951 and 1952. A summary of the research programs carried out is given in Table I.

Table I

* All chlorine titration of sea water samples was carried out by the experts in the Tokai Regional Fisheries Expt. St. under the inspection of Mr. R. Fukai.

| NO | Time | Research Ship (Organ.) | Locality | Survey |
|---|---|---|---|---|
| 1 | May, 18–22, 1951 | Shunkotsu-Maru (Tokyo University of Fisheries) | Around Hachijo Is. | Measurement by current-float & oceanographic observations (Dr. Niino) |
| | 〃 , 18 20, 1951 | Takunan-Maru (Hachijo Fish. Expt. St. | 〃 | |
| 2 | July, 17–18, 1951 | Shinyo-Maru (Tokyo University of Fisheries) | 〃 | 〃 (Dr. M. Uda) |
| | 〃 , 11–12, 〃 | Takunan-Maru | 〃 | 〃 (Dr. T. Saito) |
| | 〃 , 17–18, 〃 | (Tokai Regional Fisheries Experimental Station)* | 〃 | 〃 (Mr. T. Hirano) |
| 3 | Feb., Mar., 1952 | Tokyo University of Fish. | Sagami-Coast | 〃 (M. Uda) |
| | Feb. 6,—Mar. 2, 〃 | 4 Kaiyo-Maru (Hydr. Dept.) | Kuroshio Area | 〃 |
| | Feb. 18–22, 〃 | (Hachijo Fish. Expt. St.) | Around Hachijo | 〃 (Mr. Kanno) |
| 4 | July, 24–29, 〃 | Shinyo-Maru (Tokyo University of Fisheries) | Sunosaki—Hachijo—Aogashima | 〃 (M. Uda, T. Hirano) |
| 5 | Aug., 9–20, 〃 | Tonan-Maru (Tokyo Fish. Expt. St.) | Kuroshio & Hachijo Area | 〃 Current-meter (M. Uda, N. Watanabe) |
| | Aug., 16–22, 〃 | Umitaka-Maru (Tokyo University of Fisheries) | | |
| 6 | Sept., 3–8, 〃 | Tateyama Laboratory (Tokyo University of Fisheries) | S-W of Hachijo | Model Expt. (M. Uda, Mr. M. Ishino) |
| | Sept. 16– 〃 | Shinyo-Maru, The Patrol ships of the Maritime Safty Agency. | | Drift Subst. |

1. *The Survey of 18–22, May 1951.* Referring to Fig. 1, the currents in May show the comparatively stronger period of warm current and in some degree the after-effect of the winter monsoon. Corresponding to the Kuroshio with its axis displaced to north, a counter current appears strongly in the seas neighbouring Hachijo Is. Accordingly, turning from a SE direction towards S, then to SW and at last to

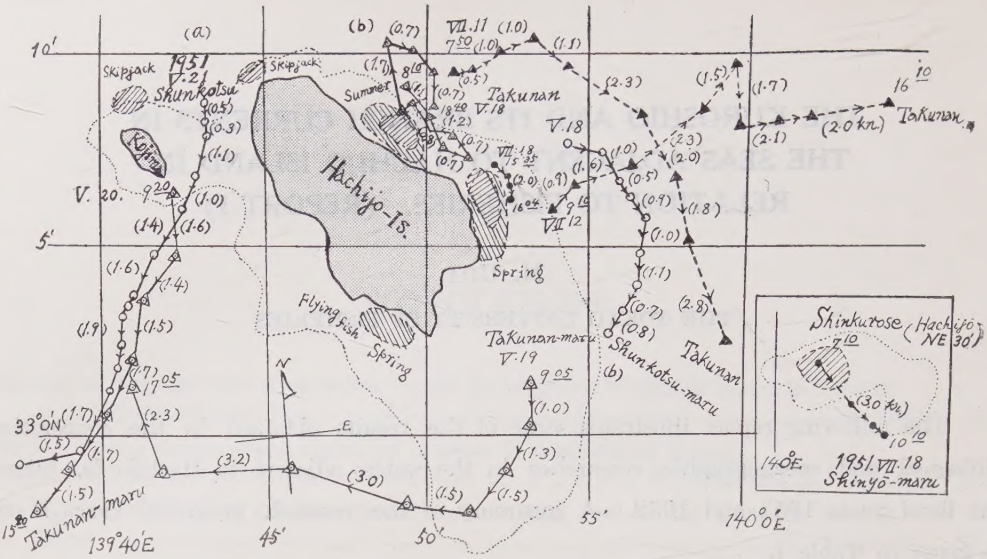



Fig. 1. Currents in May and July, 1951 around Hachijo Is. (Current-float Expt.) & fishing grounds. ▨ Skipjack ▨ Flyingfish Sypsilurus agoo (Temminck et Schlegel)

a westerly direction, Kuroshio branches flow around Hachijo. One branch of the stream-lines (a) from the region NW of Hachijo flows in a southerly direction through the channel between Hachijo Main Island and Kojima. Repeated current measurements by means of current-floats on 20 and 21 May show almost the same velocities, 1.5-1.7kn. and 0.6-1.9kn. respectively, and nearly the same trajectories. The other branch of stream-lines (b) shows the current flowing clockwise along the eastern margin of the insular shelf (near the 200 m isobath) with a velocity of 0.7-1.1 kn. and turning to a westerly direction off the southern side of the Is. with the considerably rapid velocity of 1.0-3.4 knots. Then both stream-lines (a) and (b) meet again in the region SW of Hachijo Is. at approximately 33°-00'N, 139°-40'E. There are eddies along the coast of the Island on the southern insular shelf and to the north off Kanminato. Especially in the latter area, the loop-like trajectory of the current-float of May 18th shows clearly the influence of the tidal current (of semi-diurnal nature).

Soon after the finish of the flying-fish season (Feb. 22—May 15 in 1951, poor drift gillnet catch of 1,400,000 kwan against the abundant catch of 2,400,000 kwan in 1950) in the spring our survey was conducted and the surface water temperature of 22.0-23.5° C, its salinity of 34.67-35.00‰ and its transparency of 20-30 m were obtained. It seems that the southern waters off Hachijō Is. posses a higher water temperature, salinity and transparency than do those waters to the north of the Island.

From our survey and the investigations made by the Fisheries Agency in Hachijo Is., we can conclude that the favourable fishing grounds of flying-fish correspond to

the eddies produced by the Kuroshio behind the Island and show in the abundant catches in the years of the stronger Kuroshio.

2. *The Survey of July 1951.* At a date corresponding to the closing season of Bai-U (monsoon rain in the orient), the second survey on the state of the current was carried out with a result which is very different from that above 1. After the Kuroshio aproaches from the west or southwest to Hachijo Is. its branch stream-lines envelope the Is. and then meet again behind it at about (39°-07′ N, 139°-57′ E). (See Fig. 1)

Rather than being in the transparent water with the cobalt-blue tint of the warm Kuroshio which approaches the west coast, the fishing grounds of the summer flying-fish are found in the coastal eddies off the eastern coast produced by the offshore southeast-going current and its coastal counter current. The skipjack fishing ground, however, lies in the region near the capes toward which the warm current approaches.

In this season measurements showed the surface water temperature to be 25.0-26.0° C, salinity above the 50 m depth to be 34.0-34.5 ‰ and in the layer of the 100-200 m depth to be 34.7-34.8 ‰, and transparency to be 23-32 m.

In July, compared to May, the rise in temperature and the drop in salinity in the surface layer are remarkable owing to the abundant precipitation in the rainy season (Bai-U) and also to the intensified sunshine in early summer. In this season the warm current attains its maximum intensity of the year (1-3 kn) and shows as an easterly current at the north of Hachijo and as a SE current to the east of the Island obtaining a velocity of 3 kn. in the direction S40°E over Shin-Kurose Bank. (See Fig. 1).

The rapid fluctuation of the Kuroshio in the season is evident in the contrast of the stream-lines of July 11 and July 12.

3. *Abnormal Fluctuation of the Kuroshio in the Winter of 1952.* The repeated inflow of the storm current from the offing into Sagami Bay on Feb. 8-9 (half day after the passage of the cyclone 1008 mb) and on March 27-28 (one day before the passage of the cyclone 1010 mb) washed out the set-nets arranged to catch yellow-tails along the coast of Sagami Bay and caused severe damage. On the same occassion the currents in the waters adjacent to Hachijo were observed by the fishing boat Takunan-Maru, belonging to the Hachijo Fisheries Experimental Station (the Branch Station of the Tokyo Fish. Expt. St.) and were as shown in Fig. 2a, 2b. An abnormal inflow of the Kuroshio current from the SW direction towards the south

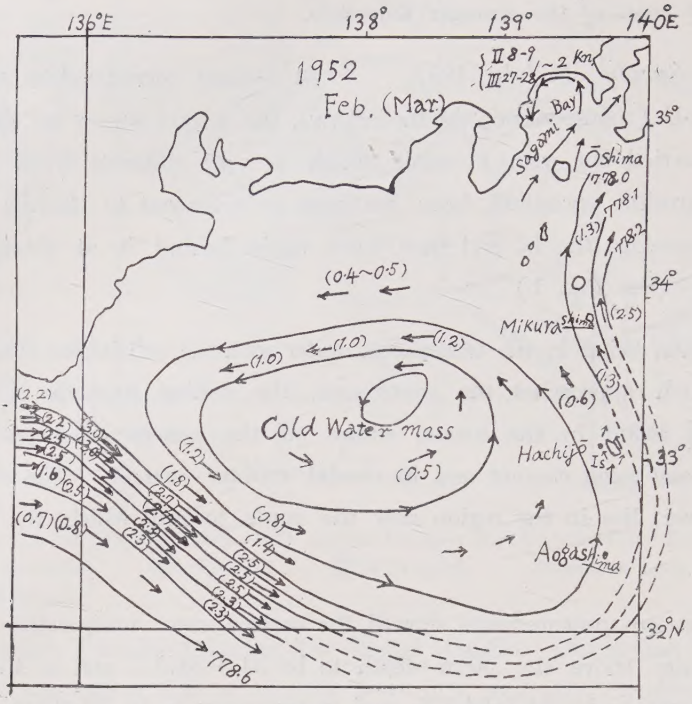



Fig. 2a. Currents in winter of 1952. (Mainly from Kaiyo-Maru, No. 4 Hydr. Dept.) (vel. in knot

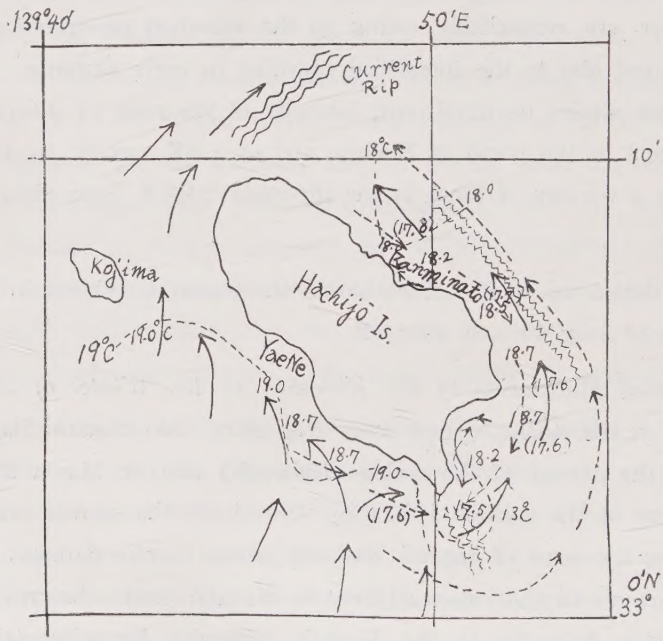



Fig. 2b. Currents around Hachijo Is. in winter of 1952 by Takunan-Maru (⟶ II. 18, 1952. ⤏ II. 22, 1952. ~~ Curr. Rips) with surface water temp. (II. 18... no parenthes. II. 22... ( ) figure)

coast of Hachijo on Feb. 18 and on Feb. 22 is indicated, showing an abrupt change of the current pattern.

According to the survey from Feb. 6 to March 2, 1952 carried out by the Kaiyo-Maru No. 4 belonging to the Japanese Hydrographic Dept*, after the counterclockwise flow around the temporarily developed cold water mass lying south off Enshū-Nada in the winter of 1952, the Kuroshio showed a violent inflow to the north directly from the region south-west of Hachijo Is. into the innermost portions of Sagami Bay. Presumably we may conclude that the above mentioned storm current along the coast of Sagami Bay is due to this abnormal northern inflow of the Kuroshio. However, in the spring (April—May) of 1952 the recovery of the Kuroshio to the normal state was proved by a survey of the same reseach boat*.

4. *The Survey of July 24-29, 1952.* The survey made by the Shinyo-

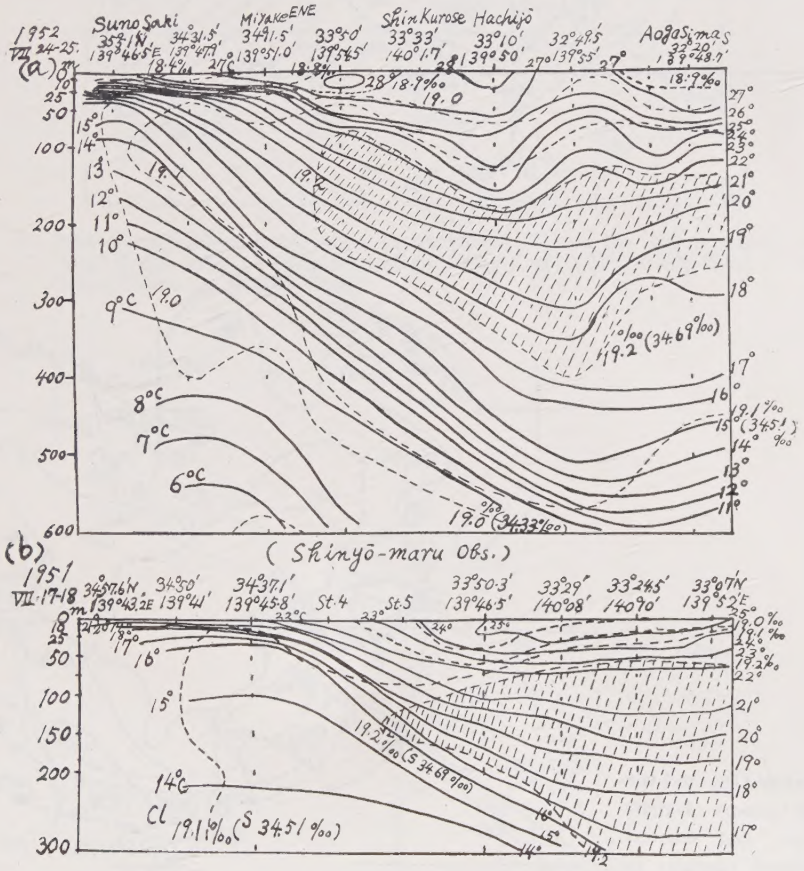



Fig. 3a, b. Hydrographic section (isotherms, isohalines) observed by "Shinyo-Maru."
(a) VII. 24~25, 1952. Sunosaki~Hachijo~Aogashima.
(b) VII. 17~18, 1951. Sunosaki~Hachijo Is.

* Refer to Hydrographic Bulletin No. 32, p. 175, 1952, Tokyo.

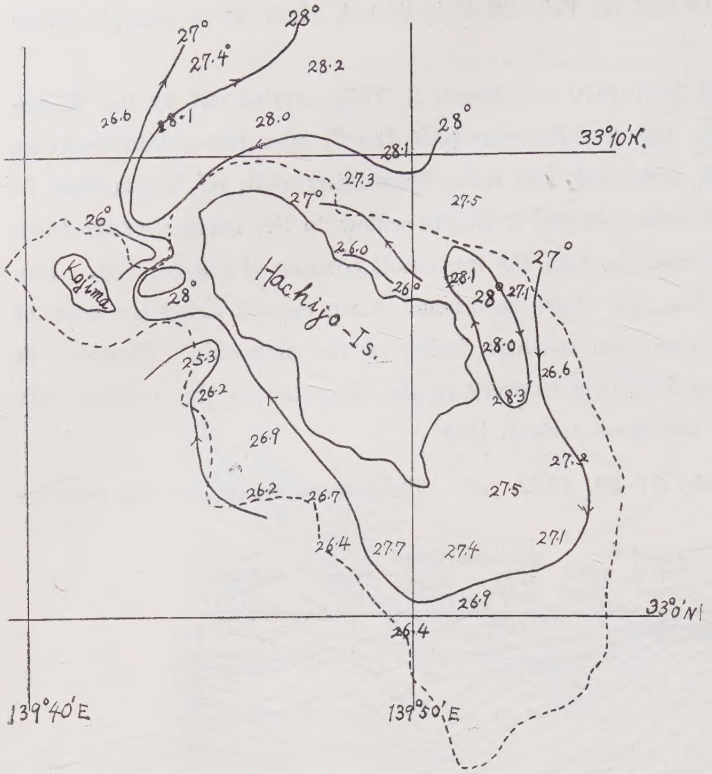



Fig. 4a. Surface water temp. (°C) around Hachijo Is. On July 26, 1952. ("Shinyo-Maru Obs.)

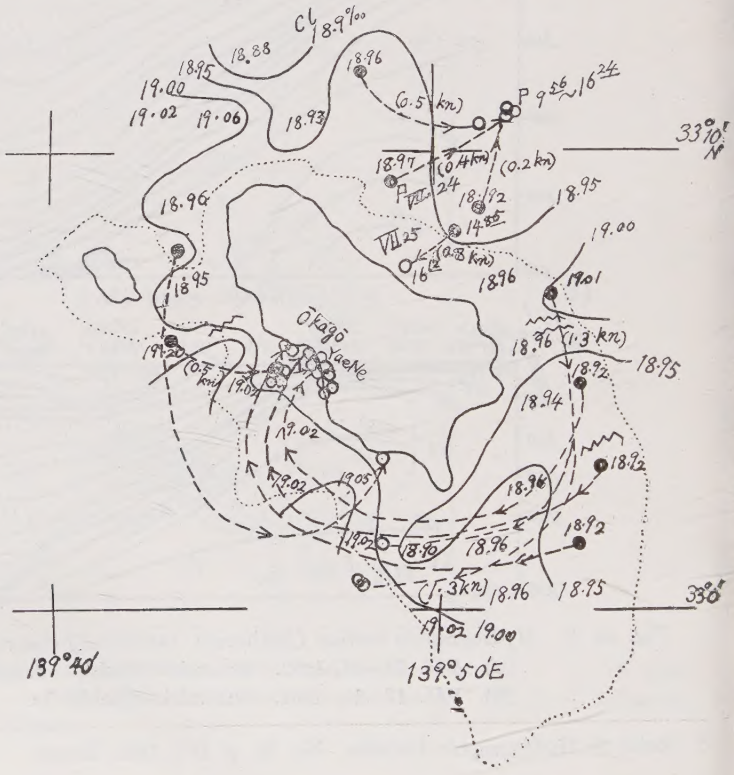



Fig. 4b. Surface Cl‰ and currents (by means of drift-card expt. and current-float) around Hachijo Is. on July 26, 1952. ("Shinyo-Maru" Obs.)

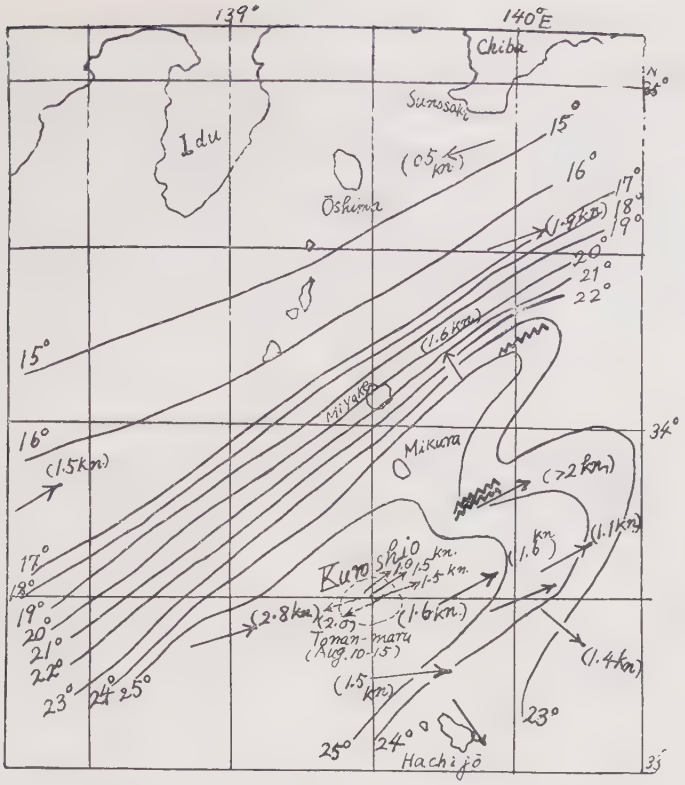



Fig. 5. Surface currents and the water temperature (°C) at the 100 m depth during VIII 21–24, 1952. ("Umitaka-Maru" Obs.) and VIII 10–15, 1952. ("Tonan-Maru" Obs. on Kurose Bank).

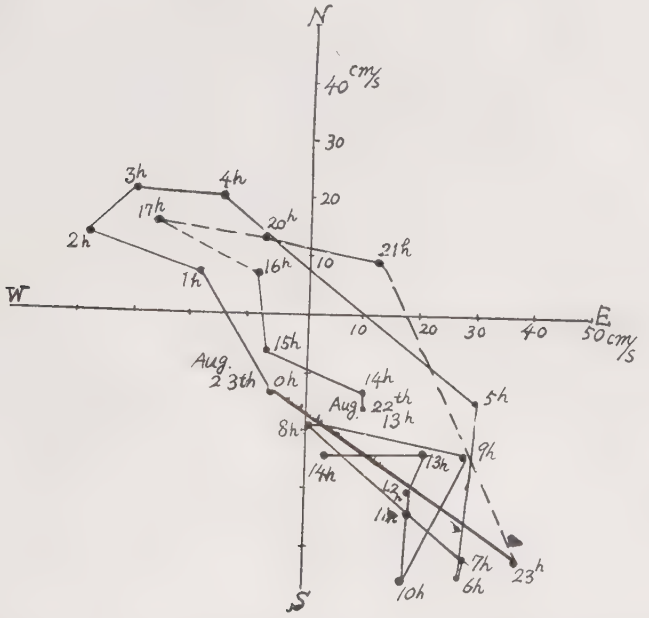



Fig. 6. Currents obtained by means of Ekman Current-meter (No. 4-35) at Kanminato (33°07.9′ N, 139°48.7′ E) Hachijo Is. on Aug. 22–23, 1952. ("Umitaka-Maru" Obs.)

Maru covered the waters from Suno-Saki to Aoga-Shima. The hydrographic section (Fig. 3a) compared to that obtained during the same period of the previous year by the same boat (Fig. 3b) indicates the intense state of the Kuroshio (higher water temperature and salinity, and stronger current north of Hachijo Is.). Three hundred drift-cards (post-card sealed in a Vinyl envelope of pink color) were thrown in the sea at 15 stations around Hachijo Is. and ten more cards were recovered which with the result of current experiments by means of current-floats showed the trajectories of the wake-streams caused by the disturbance of Hachijo Is. against the Kuroshio (Fig. 4a, b).

5. *The Surveys of August, 1952.* During the survey of August 9–20 by the fishing boat Tonan-Maru, belonging to the Tokyo Fisheries Experimental Station, and the Aug. 16–22 survey by Umitaka Maru belonging to the Tokyo University of

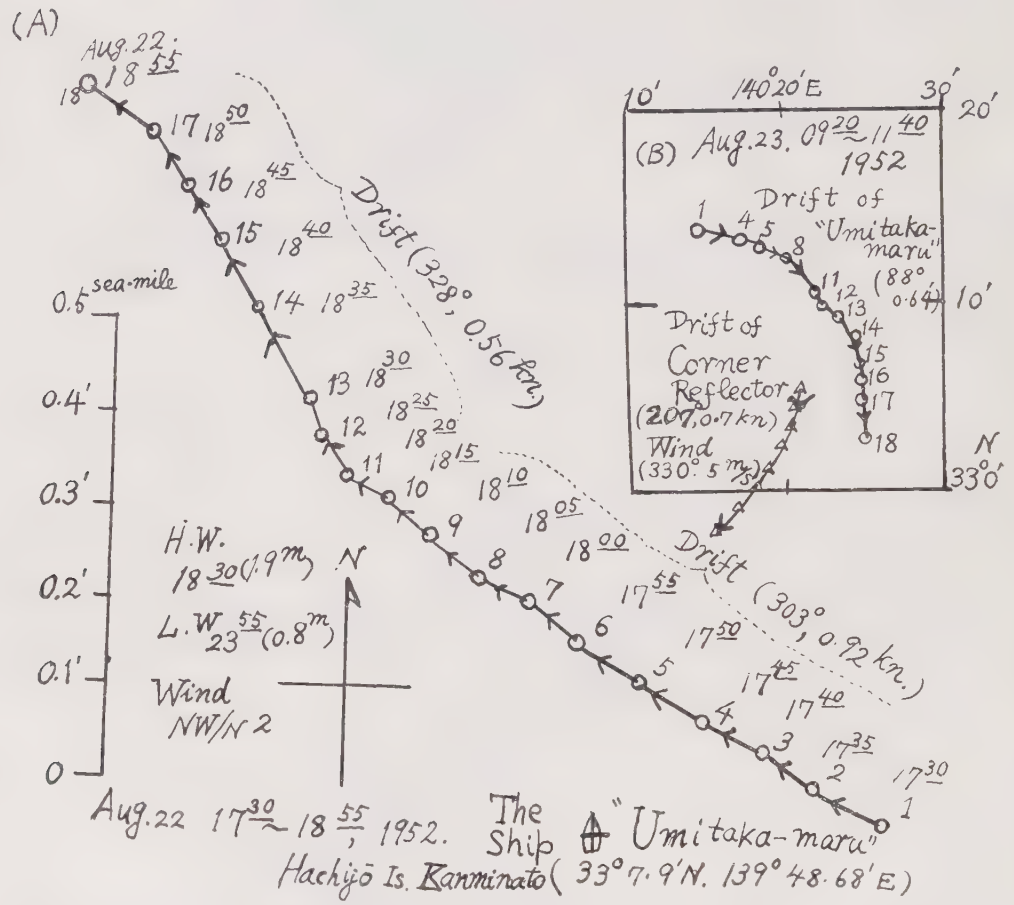



Fig. 7. Drift of the current-floats with corner-reflector observed by means of RADAR on board of "Umitaka-Maru" (Chief officer K. Ozawa) on Aug. 22–23, 1952 at Hachijo Kanminato.

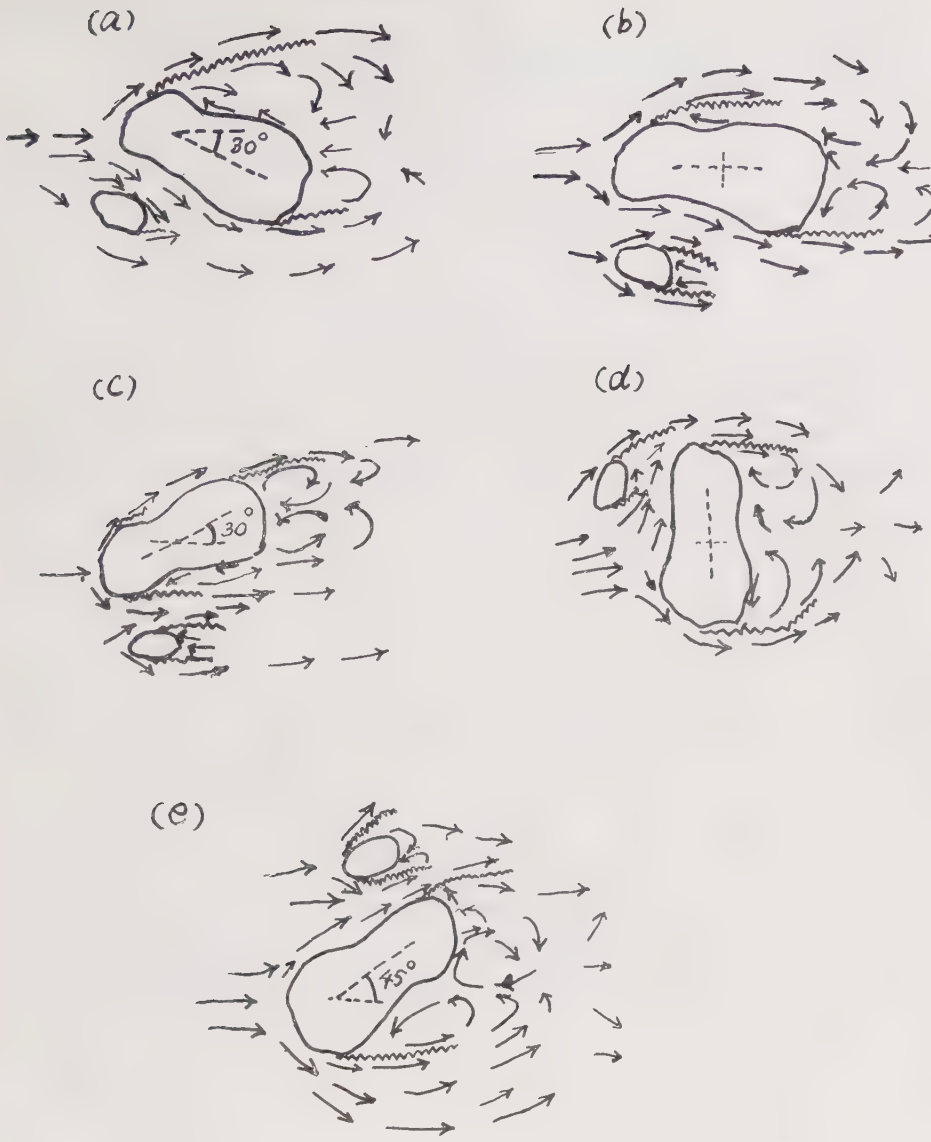



Fig. 8. Model expt. on currents around Hachijo Is. and Kojima. (based on photographs)

Fisheries hydrographic observations were carried out and from their results Fig. 5 was obtained.

Based on the result of current measurement by the Umitake-Maru using an Ekman-Merz currentmeter during 26 hours at the Kanminato anchorage station, Fig. 6 was constructed. It denotes the prevalent semi-diurnal tidal current (NW—SE) and coincides well with the result of observations by current-float off Kanminato in the preceding year. Also, obs rvations on the current trajectories on Shin-Kurose Bank

and near Hachijo Is. made by means of current-float with corner reflector were obtained successfully by the use of the Umitaka-Maru's Radar (Captain: K. Harada, Chief officer: K. Ozawa) (See Fig. 5 & 7).

6. *The Survey of Sept., 1952.* The results of model experiment in the Tateyama Marine Laboratory belonging to the Tokyo University of Fisheries by the author with the assistance of Mr. M. Ishino coincides well with the observed data. (See Fig. 8).

At about noon on Sept. 24, 1952, the volcanic explosion of Myōzin Bank (near 140° E, 31°56.5′ N) caused the tragic disaster of the No. 5 Kaiyo-Maru with the loss of 31 lives. The course of the drifting relics of the wrecked vessel and the exploded pumice-stones showed the stream-lines of the Kuroshio Counter Current to be in SSW direction with a velocity of 0.7 kn, which coincided with the observations of the coral reef expedition in the Tonan-Maru in Aug. 17–19 of this year and the past drift bottle experiments.

## *Concluding Remarks*

In the above we have found the actual state of Kuroshio with its vivid nature of fluctuation, in relation to the fishing grounds near Hachijo Island on the basis of the surveys during 1951 and 1952. The studies will be continued further.

Finally, the author wishes to express his thanks to the financial aids from the scientific reserch funds of the Ministry of Education and to the cooperation of the crews of Shinyo-Maru (Captain: M. Nagayama), Umitaka-Maru Shunkotsu-Maru, the Tokai-Regional Fisheries Research St. and the Tokyo Fisheries Expt. St. and its Hachijo and Oshima Branch St., also to Dr. Niino, Dr. T. Saito, Mr. N. Watanabe, and Mr. T. Hirano.

# ON THE CAUCHY-POISSON WAVES CAUSED BY THE ERUPTION OF A SUBMARINE VOLCANO.*

S. UNOKI

Oceanographical Section, Central Meteorological Observatory, Tokyo

and M. NAKANO

Oceanographical Laboratory, Meteorological Research Institute, and Geophysical Institute, Tokyo University

1. *Preface.* The theory of the waves produced in deep water by a local disturbance of the surface was investigated by Cauchy and Poisson independently in the case of one dimension. The similar problem in two dimensions was dealt with by Dr. H. Lamb[1] and Dr. K. Terazawa[2], but their investigations are insufficient for our purpose. Though the theory of the Cauchy-Poisson wave problems is an elegant one, the existence of such a wave in reality in the ocean has been doubted by many practitioners. Recently, however, the report of the experimental results of an atomic bomb explosion enables us to consider that the Cauchy-Poisson wave may exist in reality[3]. Here, we shall show that the Cauchy-Poisson wave occurs not only artificially and experimentally, but also actually in nature.

The position of the point where the eruption of the submarine volcano occurred and the position of Hachijo Island, where the wave was observed, are shown in Fig. 1. From the middle to the end of September, 1952, submarine eruptions occurred at a reef which is located about 300 km south of Honshu, Japan. Tsunami waves caused by some of these eruptions which were observed on September 16th, 24th and 26th, 1952 respectively are shown in Fig. 2, A, B, C. Wave observations were made at Hachijo Island, about 130km north of the submarine volcano (Myojinsho), using a self-registering wave gauge of a pressure recorder type. Wave records A, B and C in Fig. 2 are not actual data, but data adjusted to eliminate wind waves and swells, and the time

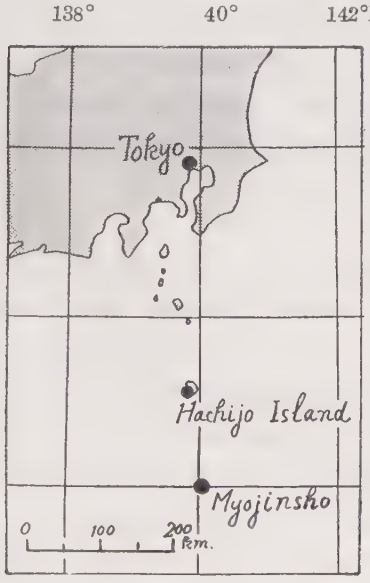



Fig. 1.

* Full discussion of this problem will be made in the *Oceanographical Magazine;* first paper-Vol. IV, No. 4, second paper.-Vol. V, No. 1, 1953.

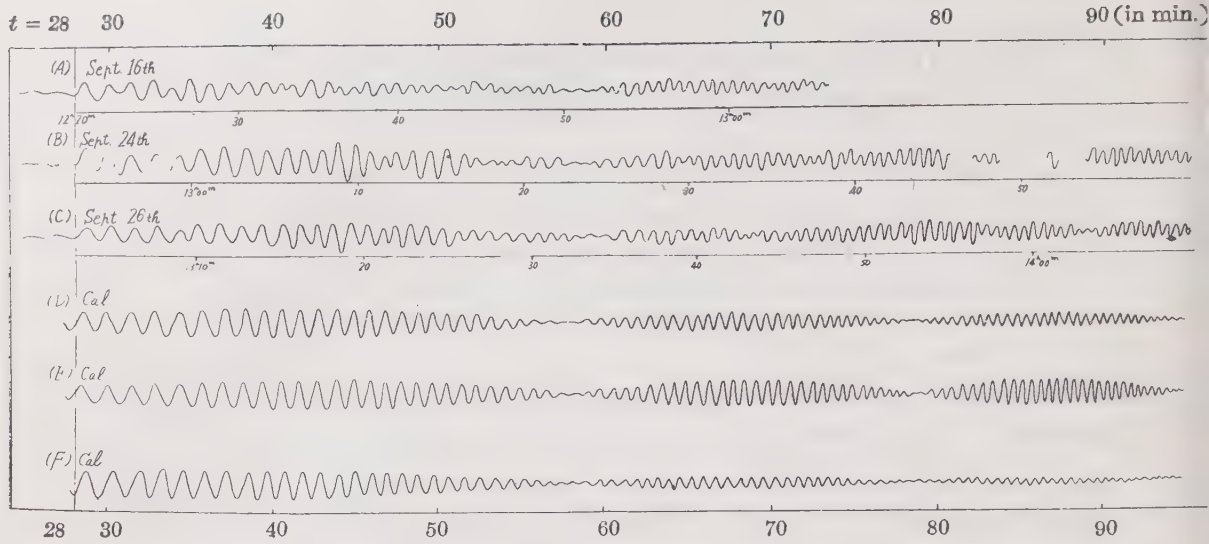



**Fig. 2.** Wave records A, B and C are the tsunamis obtained by adjusting the observed data in order to eliminate swells and wind waves. Curves D and E represent the theoretical waves caused by initial impulse, and F is the theoretical wave caused by initial elevation.

marks on wave records may have errors of the order of magnitude ±3 min. owing to the lack of a master clock for time checking. The maximum wave heights on the 16th, 24th and 26th were 56cm, 92cm and 71cm respectively, and the time necessary for propagation of tsunami from Myojinsho to Hachijo Island was 28 min. on both the 16th and the 26th. On the 24th, when the tsunami shown in Fig. 2, B was recorded—perhaps caused by the same eruption which brought disaster to the "Kaiyo-maru No. 5" of the Hydrographic Office as the ship was engaged in scientific investigation of Myojinsho —the travel time is not known because no one witnessed the eruption.

Valuable observations on the eruption at 1340 hours on the 23rd were made by members of the Myojinsho investigation party. According to their report, when the eruption occurred the sea surface, which had been even till that time, heaved up suddenly to a water dome whose dimensions were 300m wide and less than 5m high immediately after the eruption. Following this the dome became 1.5km wide and and 50～60m high, and resembled a fountain. The water which heaved up collapsed into waves of 50～60m wave length, but the wave height decreased as the party watched and was only about 1 cm when the waves reached their ship, a distance of about 1600 m. Such waves came only twice and the period was 12～13 seconds. Whether or not these waves of short wave length and small wave height correspond to the tsunami waves of our consideration is doubtful, but regardless, it can be conceived

that a particular type of wave will be generated by the collapse of such an enormous water dome.

On the other hand, it can be assumed from many facts that a strong impulse acts upon sea water at the moment of an explosion. Consequently, it is also conceivable that waves would be produced by this strong impulse.

2. *Travel time of tsunami waves.* In regard to the time necessary for the propagation of a tsunami wave, a question exists whether the wave travels with a phase velocity or with a group velocity as stated theoretically by Rossby, W.H. Munk and others. We shall here consider the problem. In our case, as the depths are 200～1400 m and the periods 30～100 sec., we should imagine the wave as a medium (elliptic trochoidal) wave rather than as a deep water wave or a long wave, considering the relative depth. For a medium (elliptic trochoidal) wave if we take period $\tau$, the wave length $\lambda$ and the depth $d$,

$$\text{phase velocity:} \quad C = \left\{\frac{g\lambda}{2\pi}\tanh\left(\frac{2\pi d}{\lambda}\right)\right\}^{\frac{1}{2}}, \qquad (1)$$

$$\text{group velocity:} \quad C_g = \frac{C}{2}\left\{1+\left(\frac{4\pi d}{\lambda}\right)\Big/\sinh\left(\frac{4\pi d}{\lambda}\right)\right\}, \qquad (2)$$

where $\lambda = C\tau$. According to A, B and C of Fig. 2, the period of the wave which first arrived is about 95 sec. On Table 1 are shown the travel times when the wave has progressed with the group velocity of a medium wave, and when a wave of a 95 sec period has progressed with the phase velocity of a medium wave and with the group velocity of a deep water wave.

The travel time is 32.1 min. if the wave has progressed with group velocity, and 28.5 min. if with phase velocity. The actual travel time, as mentioned in § 1, was about 28 min. in both the cases of 16 and 26 September.

Table 1

| Classification of velocities | $C_g$ | | | $C$ | Group velocity of deep water wave |
|---|---|---|---|---|---|
| Period $\tau$ (sec.) | 60 | 80 | 95 | 95 | 95 |
| Travel time (min.) | 41.5 | 34·3 | 32.1 | 28.5 | 30.1 |

As this value, however, can be accompanied by errors of the order of magnitude of 3 min, and it seems that the wave which first arrived has not always progressed with a constant wave form, it is difficult to determine whether the wave in the present problem has progressed with phase velocity or with group velocity. Moreover, the fact that the travel time of a deep water wave progressing with group velocity is

very near to the value of actual travel time suggests that we may most reasonably continue our discussion by assuming the wave to be a deep water one.

3. *Cauchy-Poisson wave problems in two horizontal dimensions when a local disturbance is given to a limited extent of the sea surface.* For simplification of the problem, the sea is considered to be spreading infinitely, and the depth to be very great. As a frictional force which affects wave motion, we shall take up the frictional force proportional to the velocity of fluid particles instead of eddy viscosity. S. Unoki,[4] one of the authors, has already proved that this assumptiou is almost valid in the case of waves with comparatively longer periods, and found the value of the proportional coefficient $(2\mu)$ of the frictional force to be $5.5\times10^{-4}$ c.g.s.

First, let us consider the wave caused by an initial local impulse, follwing Prof. Lamb's notation.[1] The origin of co-ordinates is taken on an undisturbed surface and cylindrical co-ordinates $z$ and $\omega$ are used, $z$ being positive upwards. Considering the above frictional force, when the initial conditions are given as

$$\zeta = 0\,, \qquad \rho\phi_0 = F(\omega), \tag{3}$$

the solution to be satisfied is

$$\phi_t = \frac{e^{-\mu t}}{\rho}\int_0^\infty\left(\cos\sigma t - \frac{\mu}{\sigma}\sin\sigma t\right)e^{kz}J_0(k\omega)kdk\int_0^\infty F(a)J_0(ka)ada, \tag{4}$$

$$\zeta_t = -\frac{e^{-\mu t}}{g\rho}\int_0^\infty\frac{\sigma^2+\mu^2}{\sigma}\sin\sigma tJ_0(k\omega)kdk\int_0^\infty F(a)J_0(ka)ada, \tag{5}$$

where the following relation must be satisfied

$$\sigma^2+\mu^2 = gk. \tag{6}$$

If the initial impulse is constant in the limited extent, then assuming

$$\rho\phi_0 = P(\omega \leqq l)\,, \qquad \rho\phi_0 = 0\ (\omega > l), \tag{7}$$

the elevation is given by

$$\zeta_t = -\frac{2^{\frac{1}{2}}\pi^{\frac{1}{2}}Ple^{-\mu t}}{\rho\omega^{\frac{1}{2}}}\Re\left[\frac{1}{2\pi}\int_0^\infty\frac{k^{\frac{1}{2}}}{\sigma}e^{i\left(\sigma t-k\omega-\frac{1}{4}\pi\right)}J_1(kl)dk\right.$$
$$\left.-\frac{1}{2\pi}\int_0^\infty\frac{k^{\frac{1}{2}}}{\sigma}e^{i\left(\sigma t+k\omega+\frac{1}{4}\pi\right)}J_1(kl)dk\right] \tag{8}$$

from (5) and (6), since

$$J_0(k\omega)\fallingdotseq\left(\frac{2}{\pi k\omega}\right)^{\frac{1}{2}}\sin\left(k\omega+\frac{1}{4}\pi\right),\ \text{in case of } k\omega \gg 1\,.$$

Using Kelvin's method regarding the principle of stationary phase, we have approxomitely

$$\zeta_t = -\frac{Plt}{2^{\frac{1}{2}}\rho\omega^2}e^{-\mu t}\sin\left(\frac{gt^2}{4\omega}\right)\cdot J_1\left(\frac{gt^2}{4\omega}\cdot\frac{l}{\omega}\right), \tag{9}$$

in the case of $\omega \gg l$, $g^2t^2/4\omega^2 \gg \mu^2$ and $\mu \ll 1$. If the initial impulse is concentrated in the immediate neighborhood of the origin and the frictional force is neglected, (9) becomes

$$\zeta_i \sim \frac{gt^3}{27\pi\rho\omega^4} \sin \frac{gt^2}{4\omega}, \tag{10}$$

which coincides with what H. Lamb obtained[1]. By comparing the solution (10) obtained by H. Lamb when the initial disturbance is concentrated at the origin, with the solution (9) obtained by us, it will be found that $e^{-\mu t}$ and $J_1\left(\frac{gt^2}{4\omega} \cdot \frac{l}{\omega}\right)$ are augmented. The former is the effect of the frictional force, and the latter is the effect of mutual interference of waves generated from the various parts of a disturbing source of finite width, thus the wave shows a remarkable "beat" phenomenon. In (9), the period of individual waves is given by

$$\tau = \frac{4\pi\omega}{gt}. \tag{11}$$

The period of the interference wave form is larger by about $(\omega/l)$ times than $\tau$. The nodes of interference waves are decided by

$$J_1\left(\frac{gt^2}{4\omega} \cdot \frac{l}{\omega}\right) = 0. \tag{12}$$

Similarly, in the case of an initial elevation applied to the undisturbed surface, with the initial conditions

$$\zeta = Q(\omega \leqq L),\ \zeta = 0(\omega > L) \text{ and } \rho\phi_0 = 0, \tag{13}$$

the elevation is given approximately by

$$\zeta_e = \frac{2^{\frac{1}{2}}QL}{\omega} e^{-\mu t} \cos\left(\frac{gt^2}{4\omega}\right) \cdot J_1\left(\frac{gt^2}{4\omega} \cdot \frac{L}{\omega}\right). \tag{14}$$

In this case also, (11) and (12) are consistent.

4. *Comparison of the theory and observed data.* The theoretical period is given by (11). The curves of the theoretical period, taking $t$ as abscissa, $\tau$ as ordinate and putting $\omega = 130$ km, are shown in Fig. 3 as A, B and C respectively.

The points superimposed on the curve in Fig. 3 are the recorded values of the period of actual tsunami waves shown by A, B and C of Fig. 2. Comparison of the theoretical curves with the observed values shows a very good agreement in all cases, both in the value of the period and in the aspect of the decrease of period with time.

The position of the node of the beat is determined by (12), consequently we can know the radius of area on which initial disturbance acts when the time of occurrence of the node is known. Hence, putting the $\omega = 130$ km and $t = 58$ min. of the first

node into the equation, we obtain $l$ (or $L$) = 2.2 km. If consideration is given to the many reports of the explosion on the 23rd stated in § 1 and to the fact that the explosions on the 16th, 24th and 26th were supposed to be of far greater magnitude, the above-mentioned values will be generally recognized as correct.

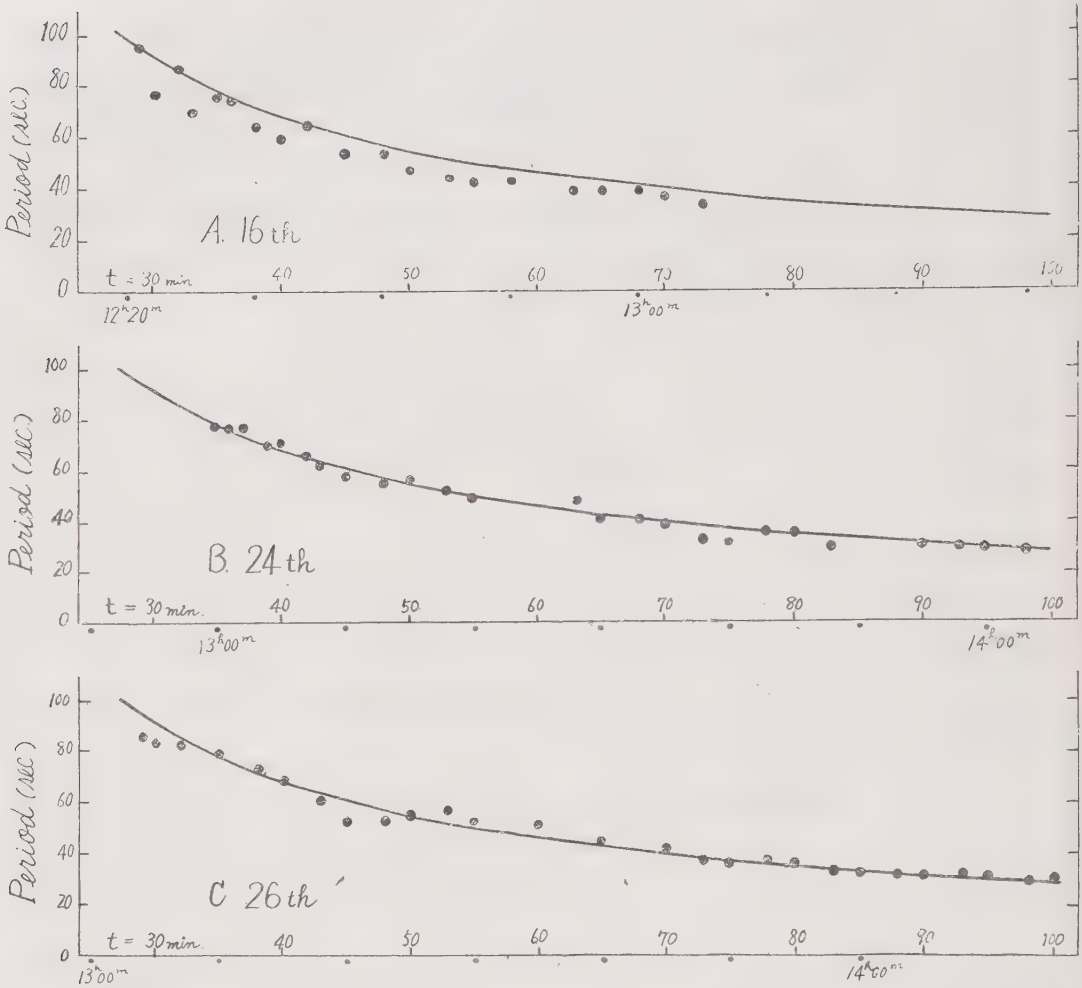



Fig. 3. Comparison of periods between theory and observation. The solid lines represent theoretical curves, while the dots represent observed values.

Now, the results of numerical calculation of solutions (9) and (14), using $l$ (or $L$) = 2.2 km, are shown in Fig. 2, D and F respectively. For purpose of reference, the theoretical elevation in case of $\mu = 0$ in (9) is shown in Fig. 2, E. Comparison of these theoretical curves, especially D, with the observed wave records A, B and C shows good agreement with regard to the variation of waves. For instance, the number of waves contained in the first beat from $t$ = 28 min. to $t$ = 58 min., is almost the same in every case. However, after the first node of $t$=58 min.

the beats occur less conspicuously, and irregularly. Especially, as the decrease of wave height generally was small, it is considered that in case of explosions the effect of the initial impulse on the generation of waves seems to be rather larger than that of the initial elevation.

Furthermore, the intensity P of the initial impulse per unit area or the height $Q$ of the initial elevation is obtained by knowing the maximum wave height and the time of its occurrence, from (9) or (14) respectively. Calculated values are shown in Table 2.

Table 2

| Sept. 1952 | A (16th) | B(24th) | C(26th) |
|---|---|---|---|
| $H_{max}$ (in cm) | 56 | 92 | 71 |
| $P$ {in (dyne/cm$^2$) × sec} | $4.2\times10^7$ | $7.0\times10^7$ | $5.4\times10^7$ |
| $Q$ (in meter) | 38 | 62 | 48 |

The values of $Q$ are in accord with the height of water dome in the observational report of § 1. On the other hand, according to the report on the cause of the disaster of the "Kaiyo-maru No. 5", it is concluded that her sinking may have occurred when the pressure 10 kg/cm$^2$ acted on the ship in the interval of 1/100 sec. Accordingly, the values of $P$ obtained are recognized to be reliable. Whether the observed tsunami waves were generated by the action of initial impulse or initial elevation is not clear, but it seems to the authors that the action of initial impulse exerts much more effect than does the initial elevation.

In any case, it can be concluded that the tsunami waves recorded recently on Hachijo Island are the typical Cauchy-Poisson waves produced by an initial disturbance of the sea surface within a limited area at the moment of the explosion of a submarine volcano.

*References*


[1] H. Lamb: *Hydrodynamics*, sixth edition, 1932, § 255; or *Lond. Math. Soc. Proc.* Vol. **II**, (2), p. 371, 1904.

[2] K. Terazawa: *Proc. Roy. Soc.* A. XCII, 57, pp. 57–81, 1915.

[3] Los Alamos Scientitic Laboratory: *The Effect of Atomic Weapons*, § 4.49～4.57, 1950.

[4] S. Unoki: *Oceanogr. Mag.* Vol. **II**, No. 1, pp. 1–15, 1950.

# ON THE EDDY DIFFUSION OF PUMICES EJECTED FROM *MYOJIN* REEF IN THE SOUTHERN SEA OF JAPAN

M. HANZAWA

Oceanographic Section, Central Meteorological Observatory, Tokyo.

1. *Preface.* On the 17th of September 1952, a new submarine volcano, located at a point* some five miles to the ENE of *Bayonnaise* Rocks, about 200 miles south of Tokyo, was first observed** erupting from the depths of the Pacific Ocean by the Japanese fishing boat *Myojin-Maru No. 11.* The Hydrographic Office of the Maritime Safety Agency of Japan named this newly formed islet *Myojin-sho* or *Myojin* Reef after the ship.

The first scientific observation of this reef was carried out by the investigation party of the Tokyo Fishery College on board the R. M. S. *Shinyo-maru*, and subsequently the Hydrographic Office dispatched the *Kaiyo-maru No. 5* (211 ton), a surveying ship, to observe and survey the reef. To our great regret, this ship was reported missing with its crew of twenty two and a nine man observation group. All men aboard the ship were believed to have met a tragic end as the result of the sudden explosion of the reef.

Wreckage of the *Kaiyo-maru No. 5* and volcanic substances were found by boats in the south-western seas near *Myojin* Reef, and later, pumice stones, which must have been ejected from *Myojin* Reef, were discovered by the Ocean Weather Ships *Ikuna-maru* and *Shiga-maru* of the Central Meteorological Observatory of Japan at points*** near the Ocean Weather Station "*Tango*" 29° N, 135° E.

From the distribution of pumice stones, the author derived an approximate magnitude of the eddy diffusion in the ocean, and gained the value

$$K = 4 \cdot 8 \times 10^6 \sim 4 \cdot 3 \times 10^7 cm^2 sec^{-1}.$$

The result of application of this value of $K$ to the so-called 4/3rd power law is shown later.

---

* 31°56.7′ N, 140°00.5′ E.

** According to Dr. R. S. Dietz[1], of the U. S. Navy Electronics Laboratory, the first eruption of this reef was recorded on Sept. 15, 1952, by the "SOFAR" hydrophones of the U. S. Navy.

*** Oct. 6, 1952 (28°56′ N, 134°28′ E); Oct. 9, 1952 (31°01′ N, 135°33′ E).

2. *General pattern of current in the vicinity of Myojin Reef.*

A) *Current velocity as computed from the drifting of the wreckage of the Kaiyo-maru No. 5.* The oceanographic investigation of the disaster of the *Kaiyo-maru No. 5* was carried out by the Oceanographic Section of the Central Meteorological Observatory, and the *Travel-time* (*Laufzeit*) diagram of the ship's wreckage clarified to some extent the general character of the current in the vicinity of *Myojin* Reef. According to this investigation[2], the direction of the current in the vicinity of the reef is generally SSW and its velocity is in the order of 0.7 knots. This current is thought to be a part of the *Kuroshio*-counter current.

B) *Past observational data obtained by the former Japanese Navy.* In December 1928, H. I. J. M. S. *Manshu* carried out an observation of current at the 10 m layer at several points in this sea region using two current meters*. The result[3] of these observations is shown in Fig. 1, which also shows the existence of the *Kuroshio*-counter current.

C) *Dynamic calculation of the density current along the so-called "G-line."* Using the data of oceanographic observations taken on board the Ocean Weather Ship *Shiga-maru*, we have computed the normal component of the surface current along the "G-line." Here, a motionless layer is assumed for a 1000-decibar surface**. The result of our computation is shown in Fig. 1 and Table 1. From these we can see that at the surface layer from St. G-1 to G-7 the eastward component of current prevailed, while on the contrary, from St. G-7 to T-1, the westward component of current prevailed at the time, October 8～13, 1952.

Considering the results mentioned above, we may assume that the centroid of a diffusing substance is such as shown in Fig. 1, and the mean velocity of the general current is in the order of 0.7 knots. The effect of leeway is neglected here, because we have no complete method to estimate it.

3. *Calculation of the eddy diffusivity.* In 1922 G. I. Taylor[4] presented a theory of diffusion in a turbulent fluid. Here, we will calculate the the eddy diffusivity in the sea using his theory. Considering from the turbulence theory, the "*Myojin* Reef case" is thought to be a case of continuous diffusion from a fixed point source. We here suppose that *Myojin* Reef, or the point source, produces a certain constant number of pumice stones in unit time.

Introducing the Lagrangian coefficient of correlation

* In this case a motionless layer was assumed to be at the depth of 800 m.

** For G-1～G-2, 700 decibar-surface.

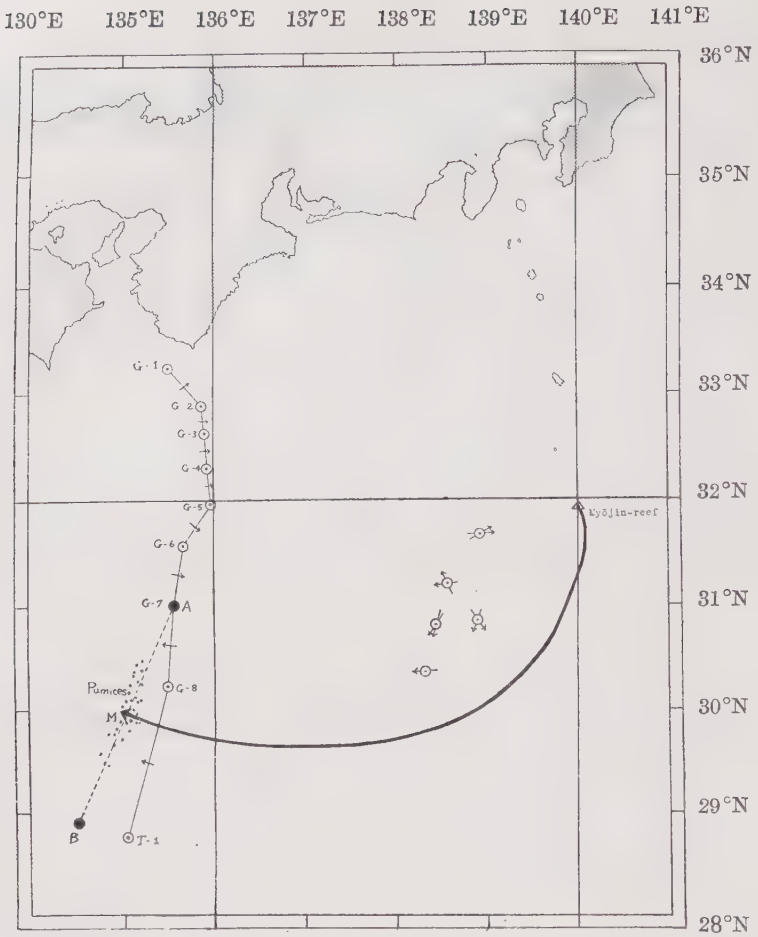



Fig. 1. Diffusing condition of pumice ejected from *Myojin* Reef. The thick full line indicates the assumed centroid of diffusion of pumice. The arrows on the "G-line" indicate E—W component of current velocity normal to that line. The arrows in the vicinity of 31° N, 139° E indicate the direction of current at the 10 m layer obtained by the *Manshu*.

Table 1. Normal component of the surface current along the "G-line."

N. B.: The mark (+) showing the east-going current, and the mark (−) the west-going one.

| Station | $G_1 \sim G_2$ | $G_2 \sim G_3$ | $G_3 \sim G_4$ | $G_4 \sim G_5$ | $G_5 \sim G_6$ | $G_6 \sim G_7$ | $G_7 \sim G_8$ | $G_8 \sim T_1$ |
|---|---|---|---|---|---|---|---|---|
| Current Velocity (kt) | +1.79 | +0.31 | +0.81 | +0.48 | +0.35 | +0.07 | −0.05 | −0.25 |

$$R_\xi = \overline{v_\xi}/\overline{v^2},$$

$v$ : the velocity of a particle at a certain instant,

$v_\xi$: the velocity of the same particle at a later time, $\xi$,

the mean distance traveled above or below the $x$-axis (centroid) of the particle is given by

$$\overline{Y^2}=2\overline{v^2}t\int_0^\infty R_\xi d\xi\ ,$$

Here $t$ is taken as $t\gg t^*=\int_0^\infty R_\xi d\xi$, because $R_\xi$ becomes $o$ for a sufficiently large value of $\xi$. Accordingly, the eddy diffusion $K$ is written as

$$K=\lim_{t\to\infty}\frac{1}{2t}\overline{Y^2}=\overline{v^2}\int_0^\infty R_\xi d\xi\ .$$

Letting $x=ut$, where $x$ is the downstream distance, and $u$ the mean velocity of the current, it appears from the above discussions that the following relation holds

$$Y^2=2Kt=2K\frac{x}{u}\ .$$

Thus, the root mean square of the distance which the pumice stones reach in an arbitrary time due to turbulence is expressed in terms of the eddy diffusivity $K$ and the time $t$. If we notice the pumice stones found on the 6th and 9th of October, and take as $x$ the downstream distance along the centroid as shown in Fig. 1, $x$ is 600 km. Further, if we take the value of $u$ 0.7 knots as indicated in Chap. 2, then,

$$t=\frac{x}{u}=\frac{600(km)}{0.7(kt)}\fallingdotseq\frac{1}{6}\times10^7(sec.)\ .$$

Now, it has been shown that the pumice stones found on the 9th of October correspond to the northern limit of diffusion, and those of the 6th of October to the southern limit, but unfortunately we have no quantitative observed data on the distribution of pumice stones between those dates. However, it has been shown that the distribution of pumice stones between $A$ and $B$ is most dense on the assumed centroid.

Thus, although we can not compute the standard deviation $\sqrt{\overline{Y^2}}$, if, for an approximate calculation, we substitute $Y$ and $1/3\,Y$ respectively for $\sqrt{\overline{T^2}}$, we have

a) In case when $\sqrt{\overline{Y^2}}=Y$, $K\fallingdotseq4.3\times10^7\ cm^2.\ sec^{-1}$. ($Y\fallingdotseq120$ km)

b) In case when $\sqrt{\overline{Y^2}}=1/3\,Y$, $K\fallingdotseq4.8\times10^6\ cm^2.\ sec^{-1}$. ($1/3\,Y\fallingdotseq40$ km)

4. *Comparison of our results with the so-called 4/3rd power law.* As is well known, V. Weizsäcker[5], W. Heisenberg[6], L. F. Richardson and H. Stommel[7] found that the coefficient of eddy diffusion in the atmosphere is proportional to the 4/3rd power of the scale of the phenomenon. Furthermore, as the result of oceanographic application of this theory, E. Inoue[8] has obtained the following empirical formula applicable to an oceanic turbulent field, *viz.*,

$$K=0.01L^{4/3}cm^2.sec^{-1}.\quad(10^{10}>L>10cm).$$

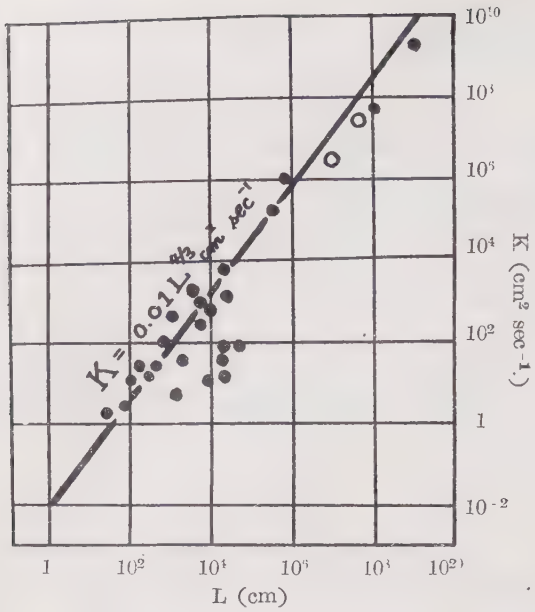



Fig. 2. Relation between the oceanic diffusion coefficient and the scale of diffusion phenomena. (After E. Inoue, 1952). White circles indicate the value obtained by the author.

In Fig. 2, the curve $K = 0.01L^{4/3}$ (shown in logarithmic scale) and some determinations of lateral eddy diffusivity including the author's, are given. Glancing at this figure we see that the value obtained by the present author conforms well with the 4/3rd power law.

As has been stated by Dr. Sverdrup *et al*[9], the computation of the eddy diffusivity in the ocean contains many bold assumptions in its present stage. Therefore, the value of $K$ obtained above indicates only the order of magnitude.

5. *Acknowledgement.* The author wishes to express his gratitude to Dr. M. Nakano, Chief of the Oceanographic Section, Central Meteorological Observatory, for his kind guidance, and to Dr. E. Inoue, of the National Institute of Agricultural Sciences, for his helpful suggestions.

*References*

[1] Dietz, R. S. (1952): On the "SOFAR" hydrophone. (Lecture delivered on the 25th of November, 1952 at the Hydrographic Office of Japan.)

[2] Oceanographic Section of the Central Meteorological Observatory of Japan. (1952): Report of investigation on the disaster of the *Kaiyo-maru No. 5* (a surveying ship of the Hydrographic Office, Maritime Safety Agency), in relation to oceanography. (In Japanese) *Oceanog. Rep. C. M. O.* (In press)

[3] Hydrographic Office (1948): Results of oceanographic observations in the North-Western Pacific Ocean. No. 1 (1923–1929). (In Japanese) *Oceanog. Bull.* No. 3.

[4] Taylor, G. I. (1922): Diffusion by continuous movements. *Proc. Lond. Math. Soc.*, **20**, 196.

[5] v. Weizsäcker, C. F. (1948): Das Spectrum der Turbulenz bei grossen Reynoldsschen Zahlen. *Z. Phys.*, **124**, 614.

[6] Heisenberg, W. (1948): Zur statistischen Theorie der Turbulenz. *Z. Phys.*, **124**, 628.

[7] Richardson, L. F. and H. Stommel (1948): Note on eddy diffusion in the Sea. *J. Met.*, **5**, 238.

[8] Inone, E. (1950a): The application of the turbulence theory to the oceanography. (In Japanese) *Journ. Met. Soc. Jap.*, **28**, No. 11.

—— (1950b): Eddy diffusion coefficient in the sea. (In Japanese) *Kagaku* (*Science*) **20**, No. 11.

—— (1952): On the structure of wind near the ground. (In Japanese) *Bull. Nat. Inst. Agric. Sci.*, Series **A**, No. 2.

[9] Sverdrup, H. U. *et al.* (1942): *The Oceans*, New York, 483.

# ON THE VARIATION OF THE OCEANOGRAPHIC CONDITION OF THE SEA NEAR THE FIXED POINT "EXTRA"

J. FUKUOKA and T. TSUIKI

Oceanographic Section, Central Meteorological Observatory, Tokyo

1. *Preface* There are many researches about the variation of water temperature in the field of physical oceanography, but most of these studies have been made using the values of the sea surface temperature and the coastal sea surface temperature. For example, the water temperature shown on the Pilot Charts is mainly the value of the sea surface temperature.

The variation of water temperature in deep layers has not yet been made clear owing to the scarcity of continuous data of serial oceanographic observations taken at a fixed point for a long time.

However, several years ago, ocean weather stations were established, and serial oceanographic observations are being made without interruption.

In Japan, the first ocean weather station was set up at the point 39° N, 153°E in the North Pacific Ocean in October 1947, and the second one at the point 29°N, 135°E in June 1949. (cf. Fig- 1)

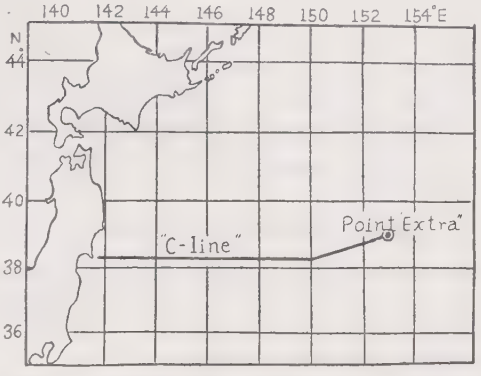



Fig. 1. Map showing "C-line" and Point "Extra".

The former station is now named "Extra" and the latter "Tango". The data of meteorological and oceanographic observations at these points are published in "The Results of Marine Meteorological and Oceanographic Observation", a quarterly bulletin of the Central Meteorological Observatory of Japan. At these fixed points oceanographic observations are usually made from surface to a depth of about 1200m about 12 ~ 24 times a month, with the main oceanographic elements observed being water temperature, chlorinity, oxygen and plankton.

In the present paper the authors intend to discuss the variation of water

temperature in deep layers using the data of observations made at the fixed point "Extra".

2. *Long periodic change of water temperature.* In the first place, the authors calculated the monthly mean water temperature of each layer. Fig. 2 shows the variation of water temperature of the layers 50m, 100m and 150m thus obtained.

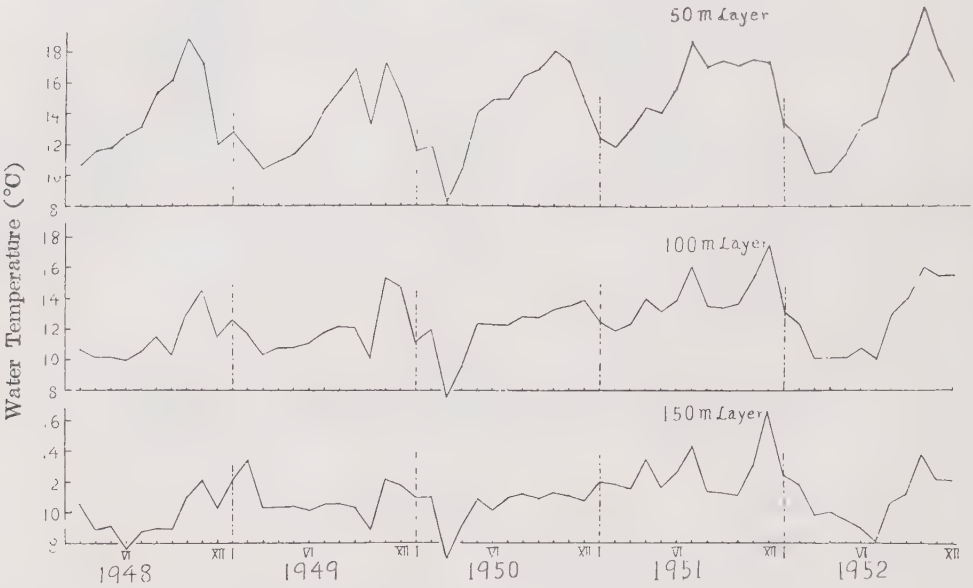



Fig. 2. The Variation of Water Temperature.

From this figure we can see that the phase of the change of water temperature of each layer is nearly coincident and the maximum temperature occurs in November or December generally.

Judging from the fact that the phase of change of each layer is nearly coincident, we many consider that this variation of water temperature is not much affected by solar radiation and other meteorological conditions, but it is the result of oceanic movement itself.

Again from Fig. 2, we can easily recognize the annual and longer periodic variations of water temperature. In order to eliminate the annual variation the method of twelve month moving average was applied to these data, the results of which are shown in Fig. 3. From Fig. 3, we can see that the water temperature was rising from 1948 to 1951 and falling since the summer of 1951.

Next, another method was adopted in order to eliminate the annual variation. In this case the monthly means of five years were calculated and the mean deviation

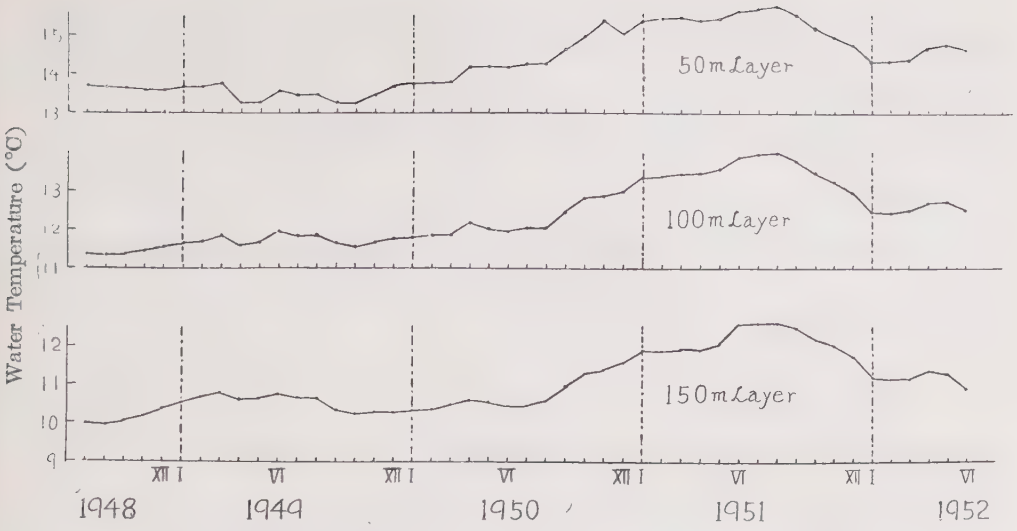



Fig. 3. The Variation of Water Temperature obtained by taking twelve Month moving Average.

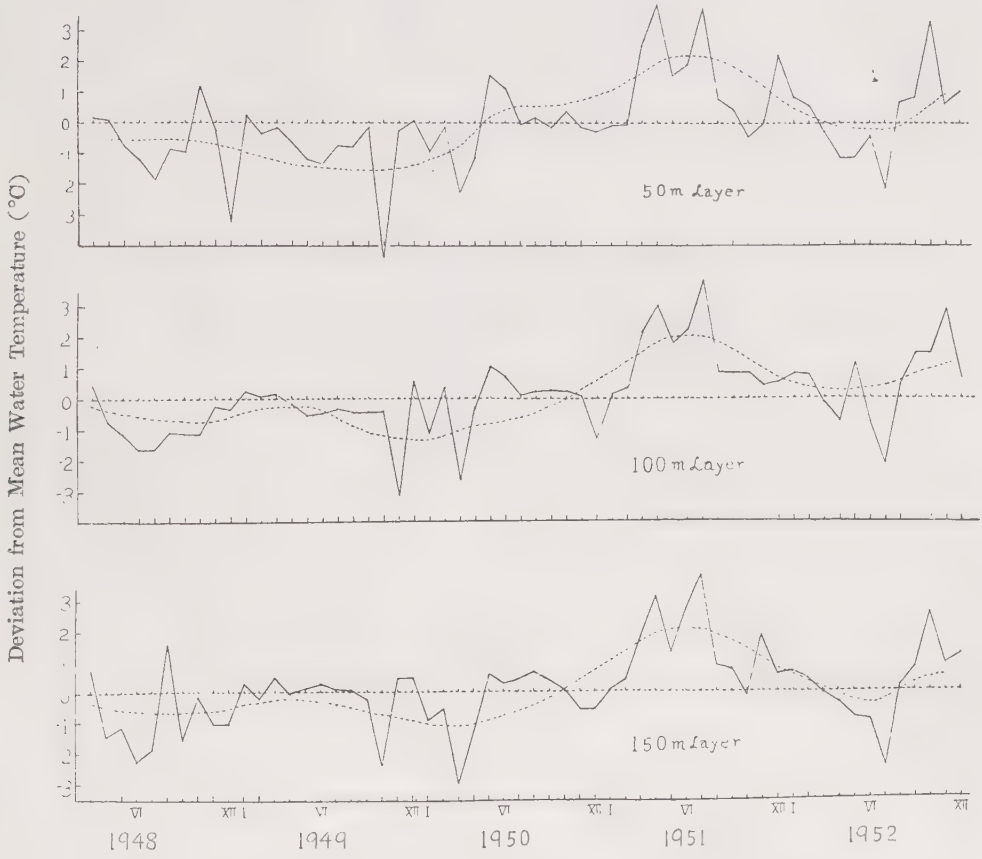



Fig. 4. The Variation of Mean Deviation from Monthly Mean Water Temperature.

from each monthly mean was computed, which is shown in Fig. 4. Looking at Fig. 4, we can see a kind of periodic variation of water temperature, whose period is longer than a year.

By the above two methods, it is known that the half period of the variation is about thirty months.

As for the cause of this periodic variation, we cannot give any definite explanation for the present, but it seems that this variation is due to a long period change of water mass situation.

3. *Short periodic change.* On the other hand, if we look at Fig. 2 a short periodic variation of the water temperature is also recognized.

Now, the maxima and minima of temperature of the 100m layer as shown in Fig. 2 were read off, and the time intervals between two maxima or minima were measured and are shown in Table 1. As seen from Table 1 the short periodic change in question has a predominant period of three months. The authors have studied the variation of water temperature along the so-called "C-line"[1] and it has been known that there exists a change of water temperature of about three months period in the sea adjacent to the Tohoku District.

Table 1.

| | | | | | |
|---|---|---|---|---|---|
| Time Interval of Temperature Maxima | Period (Months) | 3 | 4 | 5 | |
| | Frequency | 5 | 1 | 2 | |
| Time Interval of Temperature Minima | Period (Months) | 2 | 3 | 4 | 7 |
| | Frequency | 1 | 4 | 3 | 2 |

(From 100m layer)

For example, the variation of water temperature near the point 38°N, 145°E, on the "C-line" is as shown In Fig. 5. The conspicuous minima of water temp-

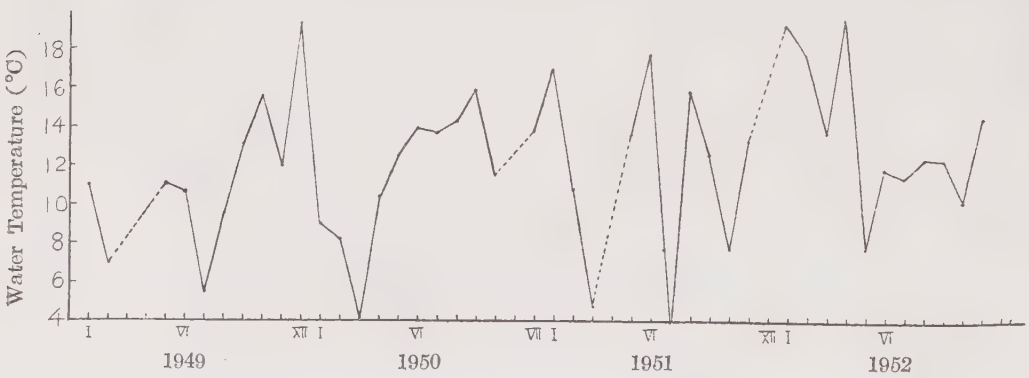



Fig. 5. The Variation of Water Temperature in 100m Layer (38° N, 145° E).

erature appearing in Fig. 5, will be due to the existence of the Oyashiwo creeping current. Mr. T. Nanniti[2] has expressed an opinion that the said periodic change will be caused by a wavy movement of the line of discontinuity between warm and cold currents.

It is hoped that the relation between the periodic change of water temperature and the movement of water mass will be thoroughly investigated in the future.

4. *Acknowledgement* The authors express their hearty thanks to Dr. M. Nakano for his encouragement and to Mr. S. Unoki for his kind help.

*References*

[1] J. Fukuoka and T. Yusa: The Variation of the Oceanic Condition in the Sea adjacent to Tohoku District. *Oceanographical Magazine*, Vol. **4** No. 2, Oct. 1952.

[2] T. Nanniti: On the Fluctuation of the Kuroshiwo and the Oyashiwo. *Papers in Meteor. and Geophy.* (The Meteorological Research Institute) Vol. **2** No. 1, 1951.

# ON THE CIRCULATION OF CURRENTS IN THE CHINA EASTERN SEA

Z. YASUI and M. MATUNO

Nagasaki Marine Observatory.

1. *Introduction.* The oceanographic observations in the China Eastern Sea were held by the Nagasaki Marine Observatory three times, from Aug. 1951 to Feb. 1952. As there was little reliable data of long continued observations, we attemped to learn the oceanographic conditions and their variations minutely by our data and utilize them for forecasting of sea conditions.

Although the synthetized reports were published after each observation in Japanese, in this paper we report with regard to the current circulation patterns and their variations and give some considerations on the prosperity and decay of the Tushima current, its counter currents and other streams.

2. *Data and method of investigations* The currents at 71 stations shown in Fig. 1 were calculated by the dynamic method in each observation. After obtaining the direction and velocity we calculated the total flow of water above 500 meters in several sections at nearly right angles to the streams. We then decided the influence and distribution of the Tsushima current, the current from the Yellow Sea and the China coastal current. Finally we considered the annual variations or fluctuations of the above currents.

Dynamic calculations are possible in the area of density currents, as in the region of the Tsushima current. But in this area the density current is small compared to the other areas of observations, so we were obliged to calculate the data on the region of high density current first and then apply those values to the calculations of the

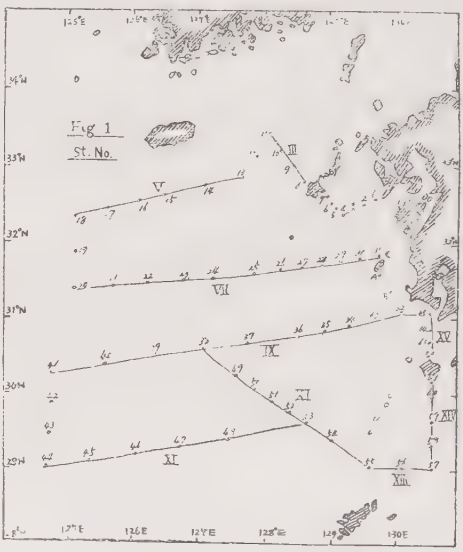
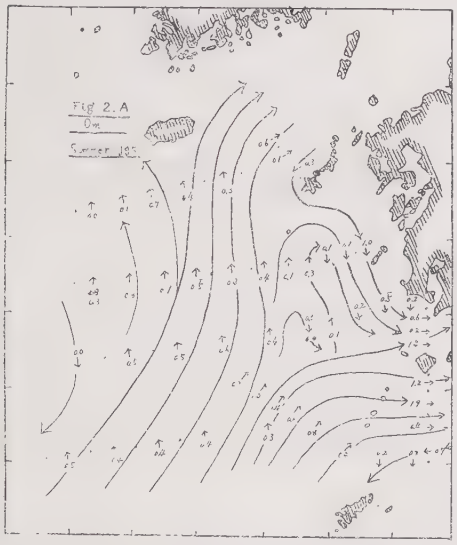


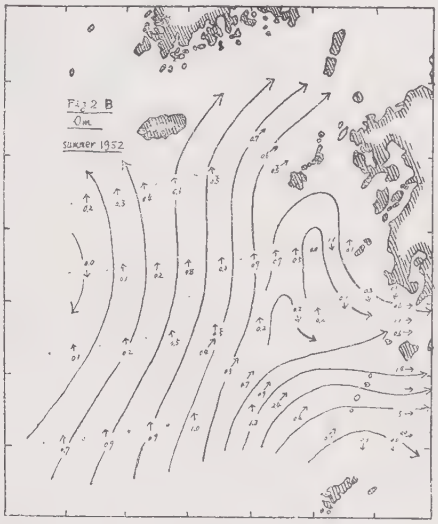

Fig. 1. Station and section numbers.

neighbouring stations in the shallow coastal water. This applied method is permitted by the fact that our purpose of investigation is the determination of comparative variations in the influences of several currents. Moreover, the actual observations of currents were carried out by drift current bottle and two current-meters, and were compared with the above mentioned calculated values.

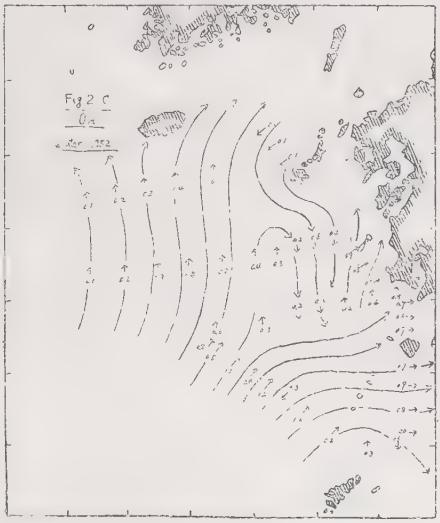
3. *General circulations in 1951 and 1952.* Fig. 2 (A—F) are charts of the distribution of general currents in Eastern China Sea on the surface and the 100 meter layer in summer 1951 and winter and summer 1952.



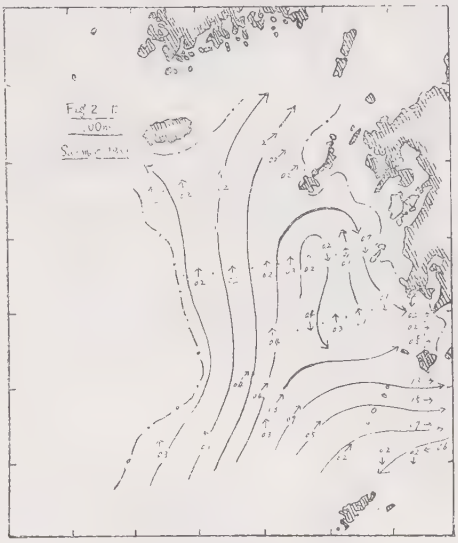

A




B

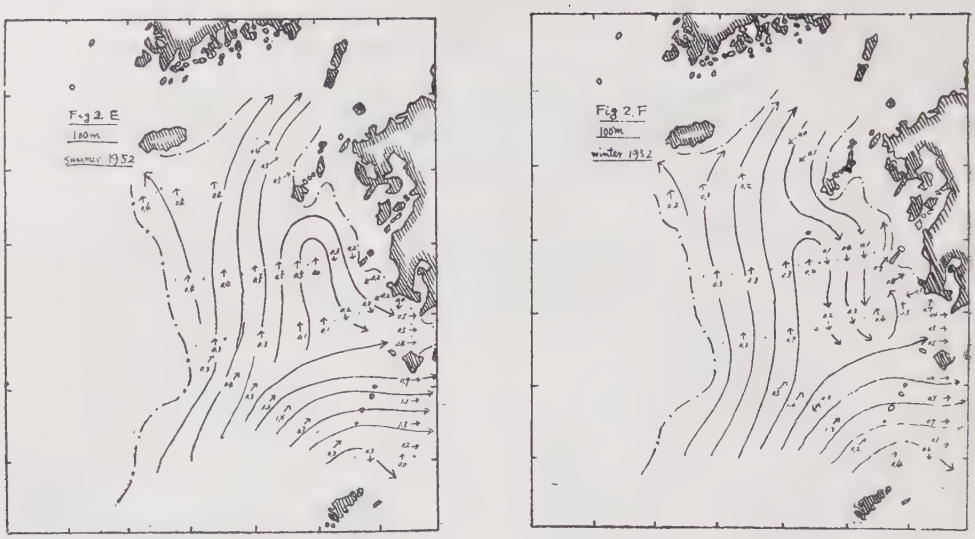



C




D

Fig. 2. A–D. Distribution of current velocity.




E F

Fig. 2. E–F. Distribution of current velocity.

In summer 1951, the max. velocity 1.9 knots easterly was observed between St. 59 and St. 60 in Sec. 14, which corresponded to the point of entrance of Kuroshio. The Tsushima currents streamed toward north about 0.4–0.6 knots. The counter currents of the Tsushima current streamed to the southward on the west coast of Kyushu, and formed a large circulation pattern.

In winter 1952, the Kuroshio became weaker and the core could not be defined clearly. The velocity of Tsusima current fell below 0.4 knots. It is known that in this season the belt of Kuroshio had shifted to the westward and the area of its counter current had spread to the west.

In summer 1952, the max. value NE'ly 2.4 knots was observed between St. 52–53 in Sec. 12, which corresponded to the area of the core which shifted to the westward in the summer. The velocity of the Tsushima current was 0.5–0.7 knots to the north.

4. *Comparison of distribution in currents.* We adopted the following formula so as to get the rate of the variation of current and made calculation at every station.

$$(V - V_0)/V_0,$$

where $V_0$ means the value of the previous season, and $V$ means the value of the present season. On the results of calculations we adopted following notations;—

(1) The directions were the same N or E in successive 2 seasons and velocity in present season increased ·····+

(2) The directions were the same N or E in successive 2 seasons and velocity in present season decreased ·····=

(3) The directions were N or E in previous season and changed to S. or W in present season, ·····///

(4) The directions were the same S or W in successive 2 seasons and the velocity in present season increased, ·····-

(5) The directions were the same S or W in successive 2 seasons and the velocity in present decreased, ·····+

(6) The directions were S or W in previous season and changed to N or E in present season, ·····※

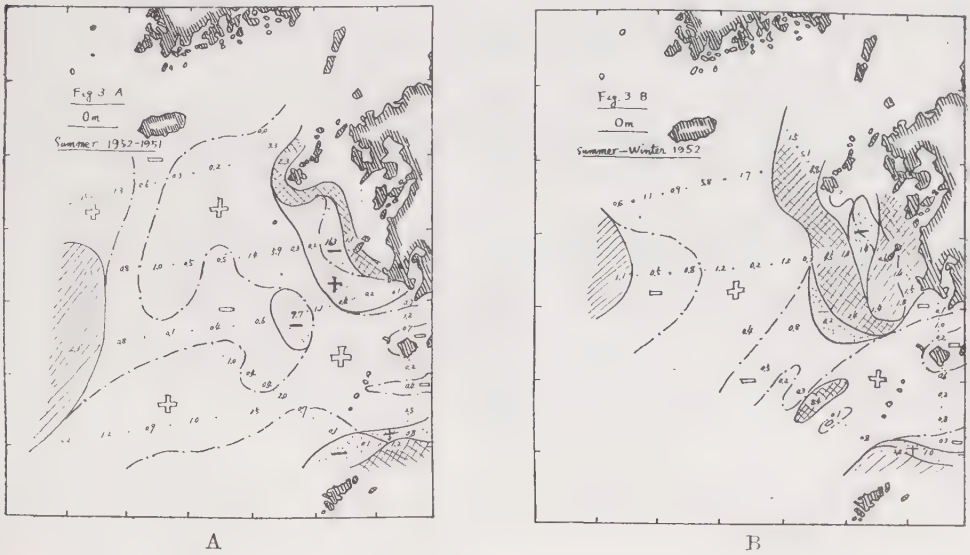
The results of calculations are shown in Tables 1 and 2. Fig. 3 (A & B) shows the comparison in variation in velocity on the surface in summer 1951 and 1952, and in winter and summer 1952. In these figures we can see the seasonal or annual variations.

(1) In summer, the Tsushima current shifted to the east from its winter course. It is supposed that the China coastal cnrrent grew in summer.

(2) In summer 1952, the Tsushima current west of Kyushu spread to the west and increased its velocity over those in summer of 1952. This also shows the influence on China coastal waters.

5. *Variation in the transportation of water into the China Eastern Sea*

The transportation of water masses through each section in unit time was calculated. The results are shown in 3. tables The quantity of the water mass transported to the




A B

Fig. 3. A-B Variation of current velocity.

Table 1. A. Variation table of current velocity (Summer 1952–1951)

| St \ Depth | 0 | 10 | 25 | 50 | 75 | 100 | 125 | 150 | 200 | 300 | 400 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4～ 5 | +0.3 | +0.3 | +0.1 | ⇒∞ | −3.1 | −0.7 | −0.3 | −0.3 | ///2.0 | | |
| 5～ 6 | ※1.4 | ※7.2 | ※5.4 | ※4.3 | ╋1.9 | ╋0.4 | ⇒1,0 | ///1.7 | ///2.0 | | |
| 6～ 7 | ///2.3 | ///8.3 | −0.5 | ⇒0.1 | −0.1 | +0.7 | +0.5 | +0.5 | | | |
| 8～ 9 | ※2.3 | ※4.3 | ╋12.0 | ╋1.9 | ╋1.5 | ╋4.3 | | | | | |
| 9～10 | ╋3.3 | ╋3.5 | ╋3.0 | ╋2.1 | ╋1.2 | ╋1.1 | ╋1.7 | ╋4.0 | | | |
| 10～11 | ⇒0.0 | ⇒0.1 | ⇒0.2 | ⇒0.3 | ╋0.3 | ╋0.5 | | | | | |
| 13～14 | ╋0.2 | ╋0.1 | ╋0.1 | ╋0.3 | ╋0.3 | ╋0.4 | ╋0.4 | | | | |
| 14～15 | ╋0.3 | ╋0.4 | ╋0.3 | ⇒0.2 | ╋0.1 | ╋0.3 | | | | | |
| 15～16 | ⇒0.6 | ⇒0.6 | ⇒0.5 | ╋0.1 | ╋0.2 | ╋0.3 | | | | | |
| 16～17 | ╋1.3 | ╋1.3 | ╋0.8 | ╋0.1 | ⇒0.1 | | | | | | |
| 17～18 | ╋15.0 | ╋1.3 | ⇒0.2 | ⇒0.1 | | | | | | | |
| 21～20 | ///1.3 | ///1.3 | ⇒0.9 | ⇒0.8 | | | | | | | |
| 22～21 | ⇒0.8 | ⇒0.9 | ⇒0.8 | ⇒0.5 | | | | | | | |
| 23～22 | ╋1.0 | ╋1.1 | ╋0.5 | ╋0. | | | | | | | |
| 24～23 | ╋0.5 | ╋0.5 | ╋0.2 | ╋0.2 | ╋0.3 | ╋0.4 | | | | | |
| 25～24 | ⇒0.5 | ⇒0.4 | ⇒0.2 | ⇒0 | ╋0,2 | ╋0.4 | | | | | |
| 26～25 | ╋1.4 | ╋1.5 | ╋1.1 | ╋1.3 | ╋1.2 | ╋0.8 | ╋0.4 | | | | |
| 27～26 | ╋5.9 | ╋2.7 | ╋1.3 | ╋0.8 | ╋0.2 | ╋0.1 | ╋0·2 | ╋0.6 | | | |
| 23～27 | ╋0.3 | ╋0.3 | ╋0.3 | ╋0.6 | ╋1.3 | ╋1.4 | ╋1.1 | ╋7.2 | 0 | 0 | |
| 29～28 | +0.2 | ∞ | +0.4 | +0.2 | +0.7 | +0.9 | ※1.1 | ※1.2 | ※1.3 | ※1.4 | 0 |
| 30～29 | −16.3 | −25.5 | −20.5 | −10.0 | ///6.0 | ///5.4 | ///5.0 | ///3.0 | ///1.4 | 0 | 0 |
| 31～30 | ※1.1 | ※1.2 | ※1.1 | +1.1 | +0.8 | +0.8 | +0.6 | | | | |
| 66～32 | +0.1 | 0 | −0.2 | −0.2 | −4.5 | +0.4 | +0.4 | −0.1 | −1.7 | | |
| 32～33 | +0.2 | +0.2 | 0 | −0.6 | −2.9 | −4.5 | −2.9 | −3.1 | −1.7 | ///1.3 | 0 |
| 32～34 | +0.4 | +0.6 | +0.6 | −0.3 | ///9.3 | ///4.1 | ///3.5 | ///2.8 | ///2.1 | ///1.8 | 0 |
| 34～35 | ╋1.1 | ╋0.5 | ⇒0 | ⇒0.4 | ⇒0.3 | ⇒0.5 | ⇒0.6 | ⇒0.8 | ⇒1.0 | ⇒0.9 | 0 |
| 35～36 | −10.0 | −7.0 | −3.2 | +0.4 | +0.9 | +1·0 | ※1.1 | ※1.2 | ⇒1.2 | +0.8 | 0 |
| 36～37 | ⇒0.6 | ⇒0.6 | ⇒0.6 | ⇒0.5 | ⇒0.5 | ⇒0.5 | | | | | |
| 37～38 | ⇒0.4 | ⇒0.4 | ⇒0.1 | ⇒0.2 | ⇒0.3 | | | | | | |
| 38～39 | ⇒0.1 | ⇒0 | ⇒0 | ⇒0.5 | ⇒0.7 | | | | | | |
| 39～40 | ⇒0.8 | ⇒0.8 | ⇒0.7 | ⇒0.7 | ⇒0.7 | | | | | | |
| 40～41 | ///2.3 | ///2.7 | ⇒0.8 | ⇒0.7 | | | | | | | |
| 45～44 | ╋0.2 | ╋0.2 | ╋0.5 | ╋0.7 | ╋0.8 | | | | | | |
| 46～45 | ╋1.2 | ╋1.3 | ╋1.2 | ╋0.9 | ╋0.8 | | | | | | |
| 47～46 | ╋0.9 | ╋0.8 | ╋0.7 | ╋0.6 | ╋0.8 | ╋0.9 | | | | | |
| 48～47 | ╋1.0 | ╋0.8 | ╋0.7 | ╋0.7 | ╋0.7 | ╋1.0 | | | | | |
| 53～48 | ╋3.5 | ╋3.6 | ╋3.5 | ╋3.1 | ╋2.6 | ╋2.2 | ╋1.9 | ╋1.7 | ╋1.2 | ╋0.7 | 0 |
| 50～49 | ╋1.0 | ╋1.2 | ╋1.0 | ╋0.5 | ╋0.1 | ⇒0.2 | | | | | |
| 51～50 | ⇒0.4 | ⇒0.4 | ⇒0.3 | ⇒0.4 | ⇒0.3 | ⇒0.4 | ⇒0.5 | ⇒0.7 | ⇒0.7 | | |
| 52～51 | ⇒0.4 | ⇒0.4 | ⇒0.3 | ⇒0.3 | ⇒0.2 | ⇒0.1 | ╋0.2 | ╋0.4 | ╋1.1 | ╋1.7 | 0 |
| 53～52 | ╋2.0 | ╋1.9 | ╋1.7 | ╋1.3 | ╋0.9 | ╋0.6 | ╋0.5 | ╋0.3 | ╋0.3 | ╋0.4 | 0 |
| 54～53 | ⇒0.7 | ⇒0.7 | ⇒0.6 | ⇒0.6 | ⇒0.5 | ⇒0.4 | ⇒0.4 | ⇒0.4 | ⇒0.2 | ╋0.3 | 0 |
| 55～54 | ⇒0.1 | ⇒0.2 | ⇒0.1 | ⇒0.1 | ╋0.1 | ╋0.1 | ╋0.3 | ╋0.5 | ╋0.2 | ⇒0.5 | 0 |
| 56～55 | −0.1 | 0 | −0.1 | 0 | 0 | −0.1 | −0.2 | −0.9 | −0.6 | ⇒0.8 | 0 |
| 57～56 | ※1.2 | ※1.2 | ※1.1 | ※1.3 | ※1.5 | ※1.6 | ※1.7 | ※1.8 | ※1.8 | +0.5 | 0 |
| 57～58 | +0.8 | +0.8 | +0.8 | +0.9 | +1.0 | ※1.1 | ※1.3 | ※1.5 | ※1.6 | +0.2 | 0 |
| 58～59 | ╋2.5 | ╋2.5 | ╋2.4 | ╋1.6 | ╋1.2 | ╋0.6 | ╋0.3 | ╋0.3 | ╋0.3 | ╋0.1 | 0 |
| 59～60 | ⇒0.4 | ⇒4.3 | ⇒0.4 | ⇒0.4 | ⇒0.3 | ⇒0.3 | ⇒0.3 | ⇒0.4 | ⇒0.4 | ⇒0.1 | 0 |
| 60～61 | ╋0.2 | ╋0.2 | ╋0.1 | 0 | ⇒0.2 | ⇒0,3 | ⇒0.4 | ⇒0.4 | | | |
| 63～64 | ⇒0.7 | ⇒0.7 | ⇒0.7 | ⇒0.7 | ⇒0.6 | ⇒0.4 | | | | | |
| 64～65 | ╋3.2 | ╋2.1 | ╋2.0 | ╋1.4 | ╋1.6 | ╋0.7 | ╋0.5 | ╋1.3 | ╋3.2 | | |
| 65～69 | ⇒0.3 | ⇒0.3 | ⇒0.1 | ╋0.3 | ╋0.5 | ╋0.8 | ╋0.8 | ╋1.2 | ╋3.2 | | |

Table 1. B. Variation table of the current velocities ( Summer—Winter, 1952)

| | 0 | 10 | 25 | 50 | 75 | 100 | 125 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1～ 2 | ※2.9 | ※2.9 | ※2.6 | ※1.5 | −0.3 | | | | | | | | | | |
| 2～ 3 | +0.8 | +0.7 | +0.3 | −0.7 | −0.3 | +0.4 | | | | | | | | | |
| 3～ 4 | −5.0 | −3.4 | −0.2 | ///2.0 | −0.2 | −0.4 | ///2.1 | ///3.4 | 0 | | | | | | |
| 4～ 5 | ///6.6 | ///5.4 | ///5.5 | ///5.5 | ///3.8 | ///2.1 | ///1.4 | ///1.2 | | | | | | | |
| 5～ 6 | ╋2.0 | ╋1.8 | ╋1.3 | ╋2.2 | ╋2.1 | ╋4.5 | ═1.0 | −2.3 | | | | | | | |
| 6～ 7 | ///2.2 | ///2.7 | ///3.7 | ///3.5 | ///2.2 | ///1.7 | | | | | | | | | |
| 8～ 9 | ※4.8 | ※5.6 | ※6.3 | ※7.6 | ※8.4 | | | | | | | | | | |
| 9～10 | ※5.1 | ※5.6 | ※6.0 | ※8.1 | ※9.0 | ※1.1 | ※2.4 | | | | | | | | |
| 10～11 | ※1.5 | ※1.3 | ※1.1 | ※1.0 | ※2.0 | ※2.1 | ※2.2 | | | | | | | | |
| 13～14 | ╋1.7 | ╋1.4 | ╋1.1 | ╋8.2 | ╋6.5 | ╋5.0 | ╋5.0 | | | | | | | | |
| 14～15 | ╋5.8 | ╋6.0 | ╋6.1 | ╋0.3 | ╋0.3 | ╋0.4 | | | | | | | | | |
| 15～16 | ╋0.9 | ╋0.6 | ╋0.5 | ╋0.6 | ╋0.5 | ╋0.5 | | | | | | | | | |
| 16～17 | ╋1.1 | ╋0.9 | ╋0.8 | ╋0.6 | ╋0.6 | | | | | | | | | | |
| 17～18 | ╋0.6 | ╋0.3 | ═0.2 | ═0.1 | | | | | | | | | | | |
| 21～20 | ///1.1 | ///1.0 | ═0.6 | ═0.5 | | | | | | | | | | | |
| 22～21 | ═0.5 | ═0.5 | ═0.5 | ═0.3 | | | | | | | | | | | |
| 23～22 | ═0.8 | 0 | ╋0.2 | ╋0.3 | ╋0.4 | | | | | | | | | | |
| 24～23 | ╋1.2 | ╋1.1 | ╋0.6 | ╋0.2 | ╋0.3 | ╋0.4 | | | | | | | | | |
| 25～24 | ╋0.2 | ╋0.4 | ╋0.4 | ╋0.4 | ╋0.4 | ╋0.4 | | | | | | | | | |
| 26～25 | ╋1.0 | ╋1.3 | ╋1.4 | ╋1.1 | ╋1.0 | ╋0.7 | ╋0.4 | 0 | | | | | | | |
| 27～26 | ╋0.3 | ╋0.2 | ╋0.2 | ╋0.2 | ╋1.3 | ╋1.0 | ╋0.9 | ╋0.8 | | | | | | | |
| 28～27 | ※4.5 | ※4.6 | ※4.6 | ※5.5 | ※7.0 | ※7.5 | ※5.9 | ※4.8 | ※3.3 | ※2.5 | ※2.4 | ※2.2 | ※1.9 | ※2.0 | 0 |
| 29～28 | ※1.0 | +1.0 | +1.0 | +0.9 | +0.9 | ※1.0 | ※1.2 | ※1.3 | ※1.6 | ※2.5 | ※2.3 | ※1.9 | ※2.0 | ※3.0 | 0 |
| A～30 | ///0.6 | −0.6 | −0.6 | −0.8 | −0.8 | ///0.9 | ///0.9 | ///1.0 | ///1.1 | ///1.3 | ///1.1 | ///1.4 | ///1.7 | ///3.0 | 0 |
| B～A | ///1.4 | ///1.4 | ///1.5 | ///1.6 | ///1.6 | ///1.5 | ///1.5 | ///1.4 | ///1.3 | ///1.1 | ///1.1 | | | | |
| 32～B | ╋1.5 | ╋0.7 | ※6.0 | ※1.8 | +0.6 | −0.3 | −0.9 | −2.0 | ///4.2 | ///2.4 | ///1.1 | | | | |
| 32～33 | ///1.8 | ///1.7 | ///1.7 | ///1.8 | ///1.9 | ///1.9 | ///1.9 | ///1.6 | ///1.3 | ///1.4 | ═0.8 | | | | |
| 33～34 | ///1.4 | ///1.3 | ///1.2 | ///1.3 | ///1.6 | ///1.6 | ///1.6 | ///1.4 | ///1.3 | ///1.1 | ═0.9 | ═0.6 | ═0.4 | ╋∞ | 0 |
| 34～35 | ※2.4 | ※2.2 | ※1.8 | ※1.5 | ※1.5 | ※1.4 | ※1.3 | ※1.1 | +0.8 | +0.9 | +0.6 | −0.2 | +0.3 | −∞ | 0 |
| 35～36 | −0.2 | −0.1 | +0.2 | +0.1 | ※1.2 | ※1.4 | ※1.6 | ※1.8 | ※1.9 | ※1.8 | ※1.8 | ※2.7 | ※2.6 | ※3.0 | 0 |
| 36～37 | ═0.8 | ═0.8 | ═0.8 | 0 | ╋0.1 | ╋0.1 | ╋0.1 | ╋0.0 | | | | | | | |
| 37～38 | ╋0.4 | ╋0.4 | ╋0.5 | ╋0.6 | ╋0.3 | ╋0.1 | | | | | | | | | |
| 50～49 | ═0.5 | ═0.5 | ═0.4 | ╋0,3 | ╋0.3 | | | | | | | | | | |
| 51～50 | ╋0.2 | ╋0.1 | ╋0.0 | ═0.2 | ═0.2 | ═0.3 | ═0.2 | ═0.1 | ═0.2 | ╋0.0 | ※3.8 | | | | |
| 52～51 | ═0.3 | ═0.2 | ═0.1 | ╋0.1 | ╋0.1 | ╋0.1 | ╋0.2 | ╋0.2 | ╋0.1 | ═0.2 | ═0.3 | ═0.5 | ═0.3 | 0 | 0 |
| 53～52 | ※8.4 | ※9.1 | ※9.0 | ※8.6 | ※8.2 | ※7.7 | ※8.2 | ※1.1 | ※3.7 | ╋7.5 | ╋4.0 | ╋0.4 | ╋0.2 | ╋0.2 | 0 |
| 54～53 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | ═0.1 | 0 |
| 55～54 | ╋0.8 | ╋0.8 | ╋0.9 | ╋0.8 | ╋0.9 | ╋0.9 | ╋0.9 | ╋0.8 | ╋0.7 | ╋1.1 | ╋2.0 | ※∞ | ※4.7 | ╋5.0 | 0 |
| 56～55 | ///2.0 | ///2.0 | ///2.0 | ///2.0 | ///2.0 | ///1.8 | ///1.7 | ///1.6 | ///1.6 | ///2.0 | ///1.8 | ///1.8 | ///3.0 | −1.0 | 0 |
| 57～56 | +1.0 | +1.0 | +1.0 | ※1.0 | ※1.0 | ※1.0 | ※1.0 | ※1.0 | +1.0 | +0.6 | −0.1 | −0.5 | −0.8 | −0.5 | 0 |
| 57～58 | ═0.3 | ═0.8 | ═1.0 | 0 | ╋1.3 | ╋2.0 | ╋3.0 | ╋2.5 | ╋0.6 | ═0.1 | ╋3.0 | ╋2.0 | ╋7.0 | ╋8.0 | 0 |
| 58～59 | ╋0.8 | ╋0.9 | ╋0.9 | ╋0.8 | ╋0.9 | ╋0.9 | ╋1.0 | ╋1.0 | ╋1.2 | ╋1.4 | ╋0.4 | ╋0.5 | ╋0.1 | ╋1.0 | 0 |
| 59～60 | ╋0.2 | ╋0.2 | ╋0.2 | ╋0.3 | ╋0.3 | ╋0.2 | ╋0.1 | ╋0.1 | ╋0.3 | ╋0.6 | ╋0.2 | ═0.2 | ═1.3 | | |
| 60～61 | ╋0.6 | ╋0.7 | ╋0.9 | ╋1.1 | ╋1.2 | ╋1.4 | ╋1.3 | ╋0.7 | | | | | | | |
| 63～64 | ═0.2 | ═0.2 | ═0.2 | ═0.1 | ═1.1 | ═0.0 | | | | | | | | | |
| 64～65 | ╋1.0 | ╋1.2 | ╋1.3 | ╋0.7 | ╋0.7 | ╋0.2 | ═0.0 | 0 | ═0.0 | | | | | | |
| 65～66 | ═0.1 | ═0.0 | ═0.1 | ╋0.5 | ╋0.6 | ╋0.4 | ╋0.3 | ╋0.2 | ═0.0 | | | | | | |

Table 2. Total flow in each section.

| Sec. No. | 1951 summer above 400m depth | | 1952 winter above 500m | | 1952 summer above 400m | | 1952 summer above 500m | |
|---|---|---|---|---|---|---|---|---|
| | ($\times 10^6 m^3$/sec) | | ( 〃 ) | | ( 〃 ) | | ( 〃 ) | |
| III | + 1.13 | | | −0.37 | + 2.73 | | + 3.09 | |
| V | + 3.16 | | + 3.04 | | + 3.86 | | + 4.69 | |
| VII | + 5.75 | −2.70 | + 4.71 | −2.79 | + 7.29 | −1.54 | + 9.81 | −1.69 |
| IX | + 9.45 | −1.13 | + 3.60 | −2.62 | + 5.18 | −2.63 | + 8.12 | −1.51 |
| XI | +11.19 | | | | +24.17 | | +30.90 | |
| XII | +15.24 | | +16.23 | | +16.19 | | +25.25 | |
| XIII | | −1.93 | | −3.52 | + 0.54 | −0.89 | | −2.27 |
| XIV | +14.49 | −2.44 | +10.89 | | +13.84 | | +16.70 | |
| XV | + 2.75 | | + 3.49 | | + 4.18 | | + 4.18 | |

east through sections 13, 14 and 15 at the origin of the Kuroshio in summer 1951 is $17.24 \times 10^6$ $m^3$/sec, while it is 18.37 in summer 1952, It shows that the influence of Kuroshio in 1952 was increased about 7% against in 1951, and the ratio of transportation on the sections was 15:14:13 = 16:84:0 in 1951, and 23:75:2 in 1952.

Now, if we consider that the stream from the south is separated into two currents, one streaming to the northward as the Tsushima current and the other progressing eastward as the Kuroshio on the west off Amami-Oshima, we can estimate the ratio of water flow of the currents in every season. The results are shown in the following Table.

The flow of Kuroshio on Summer 1952 increased a little, but the Tsushima current was less conspicuous, and the water passing through Osumi-Strait became more than that of the previous summer.

| | Total flow (10 m/sec) | Flow of Tsushima cur. | Flow of Kuroshio |
|---|---|---|---|
| 1951 Summer | 26.69 (100%) | 9.45 (35%) | 17.24 (65%) |
| 1952 Summer | 23.49 (100%) | 5.18 (22%) | 18.37 (78%) |
| '52–'51 / '51 | −12% | −45% | 7% |
| 1952 Winter | 21.50 (100%) | 3.60 (17%) | 17.90 (83%) |
| 1952 Summer | 29.07 (100%) | 5.92 (20%) | 23.15 (80%) |
| Sum.–Win. / Win | 35% | 64% | 29% |

Although the total flow of the Kuroshio in summer 1952 was 35 % more than that in winter 1952, the ratio of the above two currents was nearly equal.

6. *Conclusion.* By these investigations we recognize that the water in the China Eastern Sea is formed with ( 1 ) warm water of the Tsushima current which separated from Kuroshio, ( 2 ) its counter currents, ( 3 ) cold and less saline water of Yellow Sea, ( 4 ) China coastal water, variable in temperature, and less saline. Their distribution or circulation is not always the same, but is variable owing to their relative influence. This fact was proved by other elements of observations. The same observations must be continued for a long time, as it is a most important matter for forcasting the future states of the sea.

# ON THE ANNUAL VARIATION IN OCEANOGRAPHICAL ELEMENTS AT A FIXED POINT (39° N, 153° E) IN THE PACIFIC OCEAN

M. KOIZUMI

Meteorological Research Institute, Tokyo.

1. *Source material and methods.* The information has been taken from the data of the oceanographic observations which have been performed around the fixed point "EXTRA" (39° N, 153° E) in the Pacific Ocean by the Central Meteorological Observatory of Japan since October, 1947, where marine meteorological and aerological routine observations have been also carried out. Data obtained at about six hundreds stations, located within the area of 38° - 40° N and 152° - 154° E will be dealt with in this report. About 80% of the stations are distributed within the area of 38°40′-39°20′ N and 152°40′ - 153°20′ E; if the larger area of 38°30′ - 39°30′ N and 152°30′ -153°30′ E is taken, about 90% of them are included. The monthly mean values of several oceanographic elements have been computed, and on the basis of these means the characteristic features of the annual variation in oceanographic conditions have been investigated.

2. *Water temperature and chlorinity.* As station "EXTRA" is situated in the zone where two water masses, originating from Kuroshio and Oyashio, make contact with each other, it is covered sometimes with a water mass of Kuroshio origin, and sometimes with that of Oyashio origin. Therefore the oceanographic conditions fluctuate markedly. Even at a short distance or during a short time interval, quite different vertical distributions of water temperature and chlorinity are observed frequently. Hence, some of the individual values fluctuate markedly from the monthly mean. Since the variation caused by alternation of water mass is superimposed on the seasonal variation, monthly patterns of oceanographic elements are quite complicated.

In the upper layers, the annual variation in temperature had a maximum in late summer or early fall; the range of the variation decreases with depth, and the time of maximum temperature occurs later with increasing depth. This decrease of the range and the phase lag of maximum temperature were shown most clearly in 1948, while they were somewhat obscure in 1951. It may be concluded that the case of 1951 was due to the extraordinary variation caused by the alternation of water mass. The

thickness of the isothermal layer in late winter was 150～200 m. In late summer or early fall, the spring layer of temperature develops intensely, and at that time the gradient of 0.2°-0.3° C/m occurs between the 10 m and 25 m depths, or the 25 m and 50 m depths. During the months from April to September the temperature is higher at the surface than in the subsurface, and from October to March of the following year a reversed condition is observed. The annual variation in chlorinity in the upper layers has a maximum in spring, which is due to the effect of continued evaporation, and a minimum in fall, is caused by the heavy precipitation. The date of the extreme values occurs later with increasing depth.

The core of the intermediate water (Oyashio undercurrent) is generally decided by the layer of the minimum temperature or chlorinity in the vertical distribution. Around "EXTRA," the temperature minimum is not usually observed in the vertical distribution of monthly mean values, but in the vertical profiles of monthly mean chlorinity the minimum of 18.70‰～18.85‰ is usually found between the 400 m～500 m depths.

In the layers under the intermediate water the fluctuation becomes smaller and smaller with depth. Throughout the later two years (1950, 1951), the temperature differences between the highest and lowest temperatures in 500m, 600m, 800m 1000m, and 1500 m depth layer were about 2.5°, 1.5°, 0.8°, 0.5°, and 0.2° respectively, while the differences in chlorinity were less than 0.08‰ in any layer cited above.

3. *Colour of the sea, transparency, and plankton volume.* Although the individual values of the elements in question also fluctuate considerably for the same reasons as stated in the previous section, the characteristic features of the annual variation can be revealed when the monthly mean values are adopted.

Values of the plankton volume used here have been calculated from the settling volume of plankton collected from the 100 m depth to the surface with Kitahara's net (Hensen type, bolting silk XX13, diameter of the mouth: 25 cm).

The annual variation in the colour of the sea is similar to that of the transparency, both with two maxima, one in summer and the other in winter and two minima, occuring in spring and autumn. As to the seasonal variation in plankton volume, a very distinct maximum, a phenomenon of so called burst growth, occurs in spring and a less marked maximum in fall, and a marked minimum appears in winter, and also, in a less degree, in early fall. There are correlations between each of those three elements, and it is expected from features of their annual variations. An experimental formula $D=21.8V^{-0.25}$, where $D$ represents transparency expressed in meter

and $V$, the plankton volume in cc/m$^3$, has been determined, although somewhat unsatisfactory conditions are involved such as the disregard of composition of plankton, inequality between the values of transparency and the depth of the net haul, etc. Functional relation between colour of the sea ($F$) and transparency, and also, between plankton

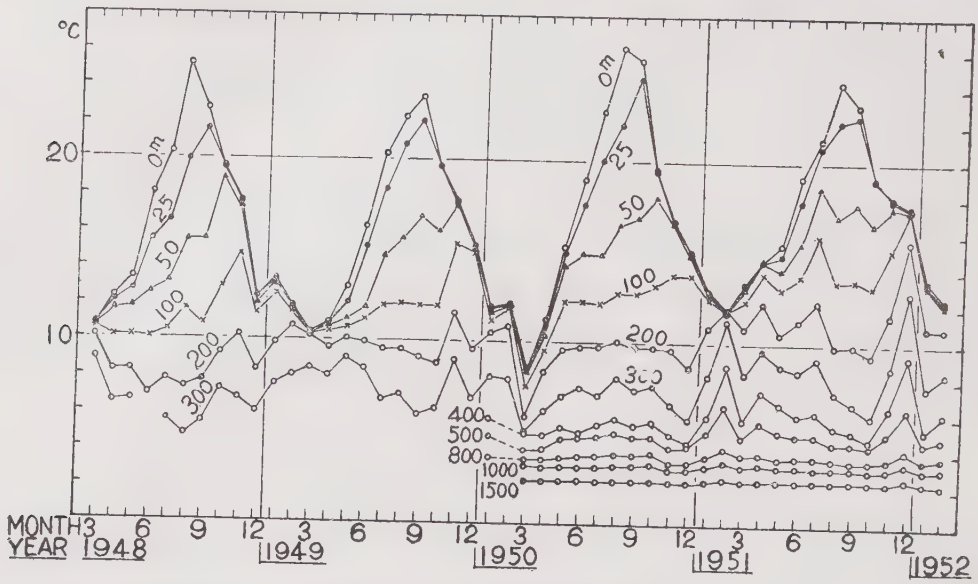



Fig. 1. Variation in water temperature at different depths.

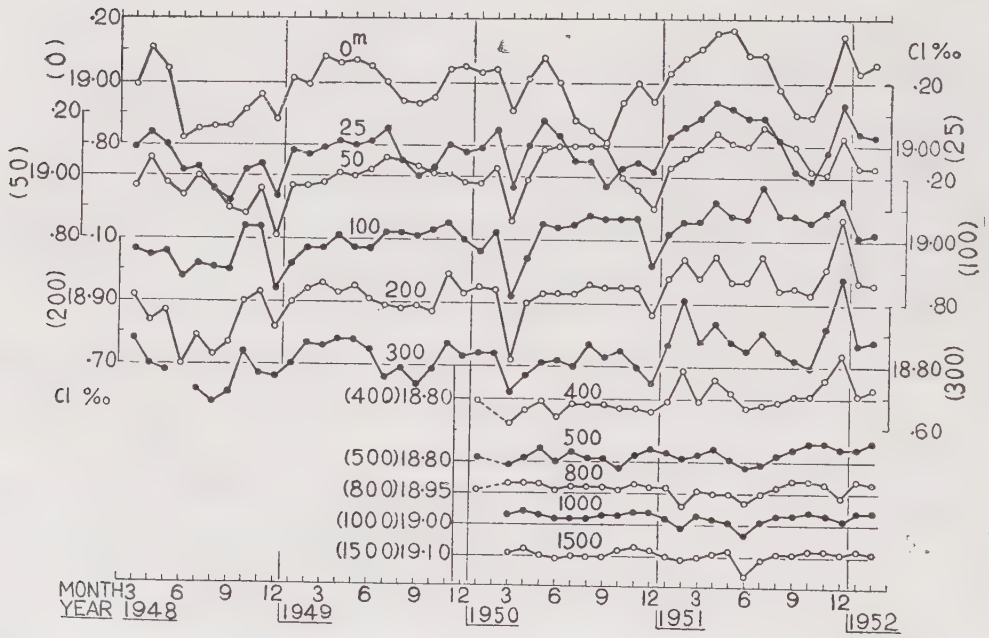



Fig. 2. Variation in chlorinity at different depths.

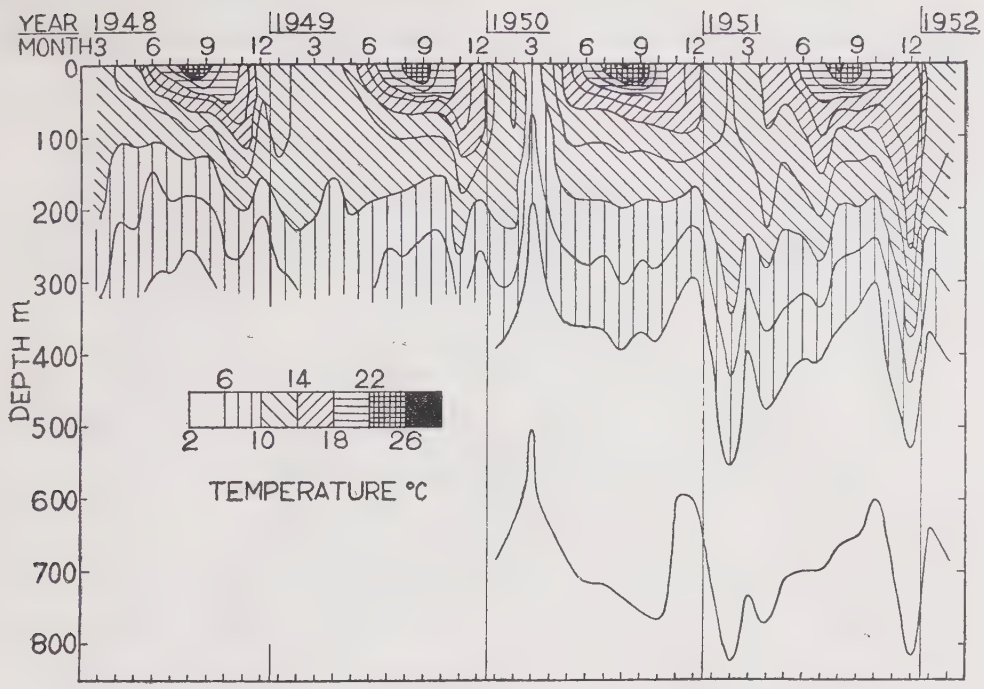



Fig. 3. Isopleth diagram of water temperature.

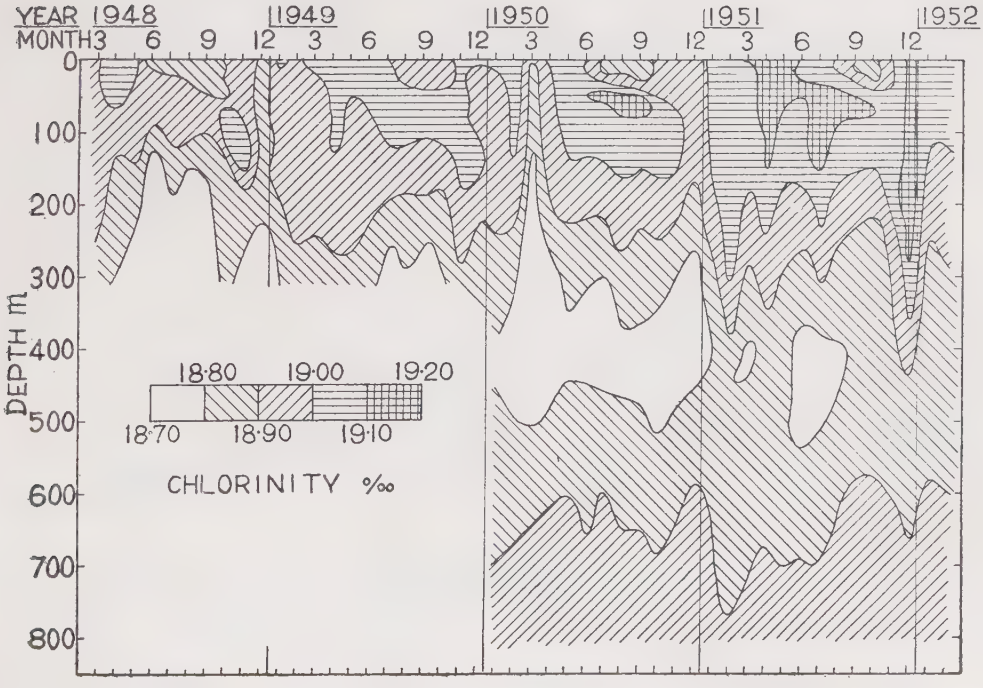



Fig. 4. Isopleth diagram of chlorinity.

volume and colour of the sea have not been determined, owing to the irregular scattering of the points on the $F$-$D$ and the $V$-$F$ diagrams. However, correlation coefficients have been computed to be $-0.67$ and 0.37 respectively.

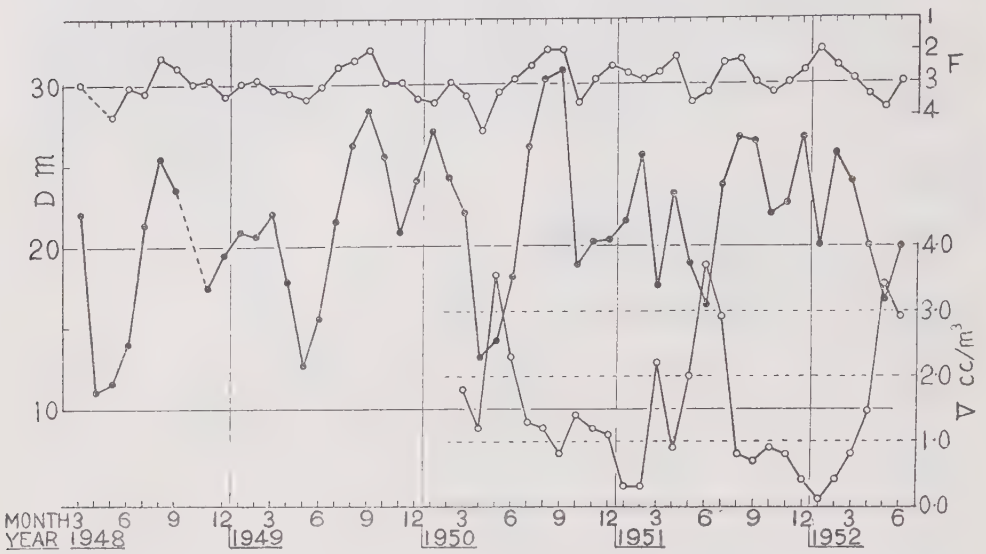



Fig. 5. Variation in colour of the sea ($F$), transparency ($D$), and plankton volume ($V$).

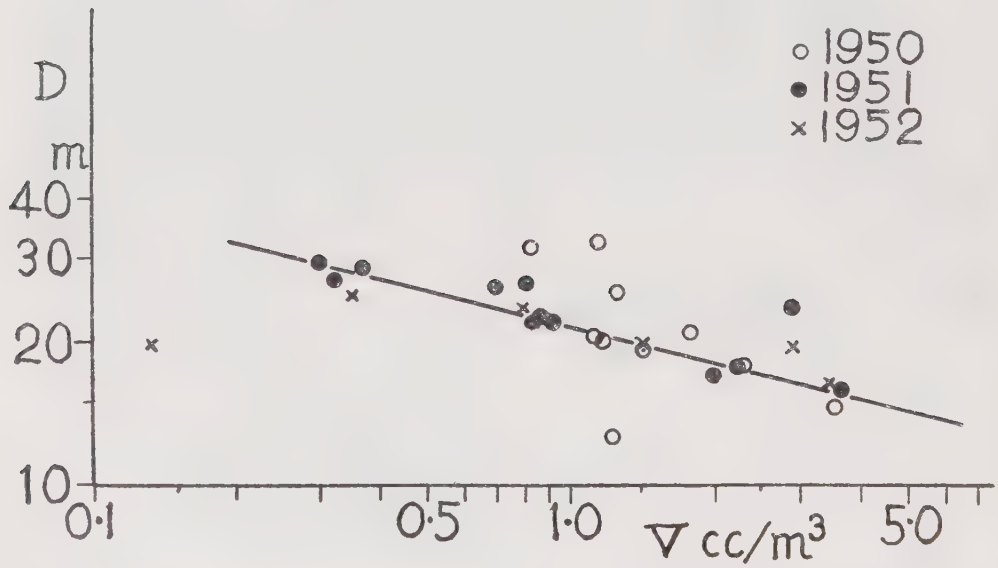



Fig. 6. Relation between transparency ($D$) and plankton volume ($V$) shown in logarithmic scale. The straight line represents $D=21.8V^{-0.25}$.

Table 1. Monthly mean values of water temperature at various depths (°C)

| Year | Depth (m) \ Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1948 | 0 | —— | —— | 10.76 | 12.23 | 13.25 | 17.96 | 20.27 | 25.23 | 22.65 | 19.40 | 17.72 | 12.34 |
| | 10 | —— | —— | 10.84 | 12.16 | 13.09 | 17.44 | 19.80 | 24.82 | 22.15 | 19.56 | 17.76 | 12.46 |
| | 25 | —— | —— | 10.80 | 12.05 | 12.70 | 15.51 | 16.50 | 19.87 | 21.64 | 19.60 | 17.62 | 12.34 |
| | 50 | —— | —— | 10.74 | 11.63 | 11.83 | 12.61 | 13.18 | 15.50 | 15.54 | 18.89 | 17.31 | 12.04 |
| | 75 | —— | —— | 10.70 | 10.87 | 11.12 | 10.74 | 11.78 | 13.11 | 12.34 | 14.84 | 16.23 | 11.84 |
| | 100 | —— | —— | 10.65 | 10.17 | 10.18 | 10.06 | 10.54 | 11.69 | 10.90 | 12.92 | 14.66 | 11.53 |
| | 150 | —— | —— | 10.59 | 8.92 | 9.18 | 7.69 | 9.18 | 8.98 | 8.98 | 11.03 | 12.32 | 10.29 |
| | 200 | —— | —— | 10.06 | 8.17 | 8.26 | 6.93 | 7.69 | 7.33 | 7.70 | 9.19 | 10.23 | 8.34 |
| | 300 | —— | —— | 8.94 | 6.60 | 6.73 | —— | 5.56 | 4.75 | 5.50 | 7.31 | 6.81 | 6.13 |
| 1949 | 0 | 12.98 | 11.67 | 10.22 | 10.94 | 12.85 | 16.18 | 20.34 | 22.31 | 23.38 | 19.58 | 17.42 | 15.12 |
| | 10 | 13.23 | 11.77 | 10.40 | 10.92 | 12.63 | 16.10 | 19.84 | 22.03 | 22.93 | 19.66 | 17.63 | 15.35 |
| | 25 | 13.20 | 11.76 | 10.41 | 10.88 | 12.05 | 15.23 | 18.26 | 20.81 | 22.06 | 19.61 | 17.61 | 15.29 |
| | 50 | 12.99 | 11.65 | 10.40 | 10.80 | 11.21 | 12.93 | 14.66 | 15.61 | 16.87 | 16.05 | 17.44 | 15.16 |
| | 75 | 12.78 | 11.62 | 10.34 | 10.52 | 10.96 | 11.87 | 13.02 | 13.44 | 13.43 | 13.32 | 16.86 | 15.11 |
| | 100 | 12.50 | 11.60 | 10.32 | 10.52 | 10.68 | 11.21 | 11.98 | 12.14 | 12.00 | 11.98 | 15.42 | 14.90 |
| | 150 | 11.72 | 11.34 | 10.30 | 10.12 | 10.34 | 10.40 | 10.75 | 10.58 | 10.26 | 10.09 | 12.87 | 11.67 |
| | 200 | 9.82 | 10.66 | 10.18 | 9.47 | 10.09 | 9.94 | 9.51 | 9.53 | 9.12 | 8.68 | 11.52 | 9.49 |
| | 300 | 7.62 | 8.13 | 8.45 | 8.09 | 9.06 | 8.51 | 6.75 | 7.12 | 6.02 | 6.31 | 8.99 | 6.85 |
| 1950 | 0 | 11.85 | 11.84 | 8.54 | 11.17 | 15.23 | 18.86 | 22.74 | 26.22 | 25.49 | 19.38 | 16.68 | 14.89 |
| | 10 | 11.89 | 12.02 | 8.56 | 11.09 | 15.09 | 18.63 | 22.41 | 25.82 | 25.05 | 19.52 | 16.72 | 15.00 |
| | 15 | 11.80 | 12.02 | 8.52 | 10.91 | 14.91 | 17.64 | 19.99 | 21.98 | 24.48 | 19.47 | 16.68 | 15.01 |
| | 50 | 11.62 | 11.96 | 8.28 | 10.39 | 14.17 | 14.93 | 14.90 | 16.47 | 16.94 | 18.03 | 16.56 | 14.81 |
| | 75 | 11.37 | 11.95 | 7.89 | 9.92 | 13.28 | 13.40 | 13.21 | 13.97 | 14.33 | 14.58 | 15.55 | 14.55 |
| | 100 | 11.16 | 11.91 | 7.57 | 9.60 | 12.34 | 12.29 | 12.20 | 12.85 | 12.77 | 13.23 | 13.77 | 13.82 |
| | 150 | 10.99 | 10.99 | 6.83 | 9.15 | 10.86 | 10.79 | 10.90 | 11.18 | 10.93 | 11.24 | 11.30 | 11.02 |
| | 200 | 10.43 | 10.76 | 5.79 | 8.32 | 9.51 | 9.68 | 9.67 | 10.02 | 9.65 | 9.74 | 9.59 | 8.61 |
| | 300 | 8.12 | 7.97 | 4.98 | 6.17 | 7.00 | 7.46 | 7.11 | 8.12 | 7.41 | 7.55 | 6.55 | 5.79 |
| | 400 | 5.82 | —— | 4.94 | 4.88 | 5.34 | 5.13 | 5.47 | 5.89 | 5.47 | 5.71 | 4.96 | 4.55 |
| | 500 | 4.76 | —— | 4.01 | 4.06 | 4.68 | 4.67 | 4.84 | 4.96 | 4.77 | 4.79 | 4.23 | 4.32 |
| | 600 | 4.27 | —— | 3.94 | 4.11 | 4.30 | 4.40 | 4.44 | 4.57 | 4.41 | 4.38 | 3.96 | 4.02 |
| | 800 | 3.56 | —— | 3.51 | 3.52 | 3.57 | 3.67 | 3.71 | 3.82 | 3.76 | 3.86 | 3.43 | 3.41 |
| | 1000 | —— | —— | 3.10 | 3.03 | 3.06 | 3.13 | 3.13 | 3.24 | 3.18 | 3.28 | 2.99 | 2.98 |
| | 1500 | —— | —— | 2.33 | 2.34 | 2.33 | 2.39 | 2.34 | 2.37 | 2.35 | 2.44 | 2.33 | 2.32 |
| 1951 | 0 | 12.80 | 11.65 | 13.22 | 14.53 | 15.35 | 19.10 | 21.21 | 24.28 | 23.08 | 19.03 | 17.89 | 17.19 |
| | 10 | 12.78 | 11.90 | 13.21 | 14.57 | 15.25 | 18.83 | 21.15 | 24.05 | 23.09 | 19.07 | 18.01 | 17.41 |
| | 25 | 12.68 | 11.92 | 13.22 | 14.54 | 14.89 | 17.79 | 20.80 | 22.24 | 22.51 | 19.00 | 17.99 | 17.43 |
| | 50 | 12.59 | 11.92 | 13.11 | 14.47 | 14.13 | 15.64 | 18.70 | 17.13 | 17.78 | 16.60 | 17.61 | 17.43 |
| | 75 | 12.56 | 11.92 | 12.70 | 14.20 | 13.58 | 14.55 | 17.13 | 14.74 | 15.02 | 14.80 | 16.88 | 17.42 |
| | 100 | 12.54 | 11.94 | 12.38 | 13.90 | 13.08 | 13.81 | 16.00 | 13.49 | 13.57 | 13.22 | 15.33 | 17.39 |
| | 150 | 11.93 | 11.88 | 11.67 | 13.37 | 11.60 | 12.57 | 14.15 | 11.52 | 11.34 | 11.12 | 13.17 | 16.64 |
| | 200 | 10.81 | 11.76 | 10.76 | 12.18 | 10.50 | 11.24 | 12.31 | 9.84 | 9.90 | 9.26 | 11.53 | 15.62 |
| | 300 | 8.13 | 11.17 | 8.30 | 9.56 | 8.83 | 8.43 | 9.22 | 7.33 | 6.65 | 6.04 | 8.73 | 12.79 |
| | 400 | 5.98 | 8.77 | 5.85 | 7.38 | 6.70 | 6.13 | 6.25 | 5.41 | 5.16 | 4.69 | 6.54 | 9.26 |
| | 500 | 5.03 | 6.51 | 4.84 | 5.64 | 5.07 | 4.91 | 4.87 | 4.49 | 4.53 | 4.30 | 5.04 | 6.38 |
| | 600 | 4.50 | 5.41 | 4.43 | 4.75 | 4.42 | 4.34 | 4.36 | 4.19 | 4.15 | 3.95 | 4.33 | 5.14 |
| | 800 | 3.73 | 4.17 | 3.76 | 3.92 | 3.68 | 3.71 | 3.65 | 3.64 | 3.53 | 3.46 | 3.61 | 4.07 |
| | 1000 | 3.15 | 3.45 | 3.16 | 3.29 | 3.18 | 3.20 | 3.13 | 3.12 | 3.09 | 3.00 | 3.11 | 3.40 |
| | 1500 | 2.37 | 2.50 | 2.40 | 2.43 | 2.38 | 2.39 | 2.37 | 2.37 | 2.35 | 2.33 | 2.35 | 2.52 |

Table 2. Montnly mean values of chlorinity at various depths (‰)

| Year | Depth (m) \ Month | Jan. | Feb. | Mar | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1948 | 0 | —— | —— | 18.99 | 19.11 | 19.04 | 18.82 | 18.85 | 18.86 | 18.86 | 18.91 | 18.96 | 18.88 |
| | 10 | —— | —— | 19.00 | 19.06 | 19.01 | 18.87 | 18.83 | 18.83 | 18.82 | 18.89 | 18.95 | 18.85 |
| | 25 | —— | —— | 18.99 | 19.04 | 19.00 | 18.92 | 18.93 | 18.86 | 18.82 | 18.92 | 18.94 | 18.84 |
| | 50 | —— | —— | 18.97 | 19.06 | 18.98 | 18.94 | 19.00 | 18.95 | 18.90 | 18.88 | 18.96 | 18.81 |
| | 75 | —— | —— | 18.97 | 18.99 | 18.97 | 18.92 | 18.98 | 18.92 | 18.94 | 19.07 | 18.99 | 18.80 |
| | 100 | —— | —— | 18.97 | 18.95 | 18.96 | 18.88 | 18.92 | 18.91 | 18.90 | 19.04 | 19.04 | 18.84 |
| | 150 | —— | —— | 18.96 | 18.87 | 18.89 | 18.72 | 18.87 | 18.80 | 18.82 | 18.97 | 19.01 | 18.89 |
| | 200 | —— | —— | 18.92 | 18.84 | 18.87 | 18.70 | 18.79 | 18.73 | 18.77 | 18.90 | 18.93 | 18.82 |
| | 300 | —— | —— | 18.88 | 18.80 | 18.78 | —— | 18.72 | 18.68 | 18.71 | 18.84 | 18.77 | 18.76 |
| 1949 | 0 | 19.01 | 18.99 | 19.08 | 19.06 | 19.07 | 19.05 | 19.00 | 18.94 | 18.93 | 18.95 | 19.04 | 19.05 |
| | 10 | 19.00 | 18.97 | 19.01 | 19.04 | 19.00 | 19.05 | 19.01 | 18.91 | 18.90 | 18.93 | 19.00 | 18.99 |
| | 25 | 18.98 | 18.97 | 18.99 | 19.01 | 19.00 | 19.01 | 19.05 | 18.95 | 18.90 | 18.93 | 19.00 | 18.98 |
| | 50 | 18.97 | 18.97 | 18.98 | 19.01 | 19.00 | 19.02 | 19.06 | 19.05 | 19.03 | 19.01 | 19.01 | 18.98 |
| | 75 | 18.97 | 18.96 | 18.97 | 19.00 | 18.98 | 19.00 | 19.04 | 19.05 | 19.05 | 19.04 | 19.01 | 18.96 |
| | 100 | 18.92 | 18.97 | 18.97 | 19.01 | 18.97 | 18.97 | 19.02 | 19.02 | 19.01 | 19.03 | 19.05 | 19.00 |
| | 150 | 18.93 | 18.96 | 18.97 | 18.99 | 18.95 | 18.94 | 18.96 | 18.95 | 18.94 | 18.94 | 19.05 | 19.01 |
| | 200 | 18.90 | 18.94 | 18.96 | 18.93 | 18.95 | 18.91 | 18.89 | 18.88 | 18.89 | 18.87 | 18.99 | 18.93 |
| | 300 | 18.80 | 18.87 | 18.86 | 18.88 | 18.88 | 18.85 | 18.76 | 18.79 | 18.74 | 18.79 | 18.87 | 18.83 |
| 1950 | 0 | 19.03 | 19.04 | 18.91 | 19.01 | 19.08 | 19.00 | 18.88 | 18.85 | 18.81 | 18.94 | 19.00 | 18.94 |
| | 10 | 19.00 | 19.04 | 18.88 | 19.00 | 19.08 | 18.99 | 18.86 | 18.84 | 18.80 | 18.93 | 18.95 | 18.93 |
| | 25 | 18.99 | 19.03 | 18.87 | 19.00 | 19.08 | 19.03 | 18.95 | 18.95 | 18.87 | 18.93 | 18.95 | 18.92 |
| | 50 | 18.98 | 19.03 | 18.86 | 18.99 | 19.09 | 19.10 | 19.10 | 19.10 | 19.10 | 19.00 | 18.96 | 18.90 |
| | 75 | 18.97 | 19.02 | 18.84 | 18.96 | 19.08 | 19.08 | 19.08 | 19.11 | 19.10 | 19.08 | 19.01 | 18.90 |
| | 100 | 18.96 | 19.02 | 18.82 | 18.94 | 19.05 | 19.04 | 19.05 | 19.08 | 19.07 | 19.07 | 19.07 | 18.92 |
| | 150 | 18.95 | 18.98 | 18.78 | 18.94 | 18.99 | 18.98 | 18.99 | 19.01 | 19.00 | 19.01 | 19.01 | 18.92 |
| | 200 | 18.95 | 18.94 | 18.72 | 18.90 | 18.93 | 18.93 | 18.93 | 18.96 | 18.95 | 18.95 | 18.95 | 18.86 |
| | 300 | 18.84 | 18.84 | 18.72 | 18.77 | 18.81 | 18.82 | 18.80 | 18.87 | 18.83 | 18.85 | 18.80 | 18.75 |
| | 400 | 18.79 | —— | 18.72 | 18.76 | 18.79 | 18.74 | 18.78 | 18.78 | 18.78 | 18.77 | 18.77 | 18.76 |
| | 500 | 18.81 | —— | 18.79 | 18.81 | 18.84 | 18.80 | 18.83 | 18.81 | 18.81 | 18.78 | 18.82 | 18.84 |
| | 600 | 18.86 | —— | 18.87 | 18.89 | 18.90 | 18.87 | 18.90 | 18.87 | 18.87 | 18.85 | 18.88 | 18.91 |
| | 800 | 18.96 | —— | 18.98 | 18.93 | 18.98 | 18.96 | 18.97 | 18.97 | 18.97 | 18.96 | 18.98 | 18.97 |
| | 1000 | —— | —— | 19.03 | 19.04 | 19.03 | 19.02 | 19.02 | 19.02 | 19.03 | 19.03 | 19.04 | 19.04 |
| | 1500 | —— | —— | 19.11 | 19.12 | 19.10 | 19.09 | 19.10 | 19.10 | 19.10 | 19.12 | 19.13 | 19.12 |
| 1951 | 0 | 19.03 | 19.08 | 19.11 | 19.16 | 19.17 | 19.09 | 19.09 | 18.98 | 18.90 | 18.89 | 18.98 | 19.15 |
| | 10 | 19.03 | 19.06 | 19.09 | 19.14 | 19.12 | 19.08 | 19.07 | 18.97 | 18.89 | 18.88 | 18.98 | 19.14 |
| | 25 | 19.03 | 19.06 | 19.09 | 19.14 | 19.12 | 19.09 | 19.09 | 19.02 | 18.92 | 18.89 | 18.98 | 19.13 |
| | 50 | 19.03 | 19.06 | 19.09 | 19.14 | 19.11 | 19.10 | 19.16 | 19.12 | 19.10 | 19.02 | 19.01 | 19.13 |
| | 75 | 19.03 | 19.06 | 19.07 | 19.13 | 19.09 | 19.09 | 19.18 | 19.11 | 19.11 | 19.10 | 19.07 | 19.14 |
| | 100 | 19.02 | 19.06 | 19.06 | 19.12 | 19.08 | 19.07 | 19.17 | 19.08 | 19.08 | 19.06 | 19.09 | 19.13 |
| | 150 | 19.01 | 19.06 | 19.03 | 19.10 | 19.02 | 19.02 | 19.11 | 19.01 | 19.01 | 19.00 | 19.07 | 19.18 |
| | 200 | 18.98 | 19.04 | 18.98 | 19.05 | 18.97 | 18.97 | 19.05 | 18.94 | 18.95 | 18.93 | 19.01 | 19.17 |
| | 300 | 18.87 | 19.01 | 18.88 | 18.94 | 18.88 | 18.85 | 18.91 | 18.85 | 18.82 | 18.80 | 18.92 | 19.08 |
| | 400 | 18.79 | 18.89 | 18.79 | 18.86 | 18.82 | 18.77 | 18.78 | 18.79 | 18.81 | 18.81 | 18.86 | 18.94 |
| | 500 | 18.83 | 18.81 | 18.82 | 18.84 | 18.81 | 18.78 | 18.79 | 18.82 | 18.84 | 18.86 | 18.86 | 18.84 |
| | 600 | 18.89 | 18.84 | 18.87 | 18.87 | 18.85 | 18.83 | 18.85 | 18.89 | 18.91 | 18.91 | 18.89 | 18.85 |
| | 800 | 18.97 | 18.91 | 18.96 | 18.95 | 18.95 | 18.92 | 18.95 | 18.97 | 18.99 | 18.99 | 18.98 | 18.94 |
| | 1000 | 19.02 | 18.99 | 19.03 | 19.02 | 19.01 | 18.97 | 19.01 | 19.03 | 19.03 | 19.04 | 19.03 | 19.01 |
| | 1500 | 19.10 | 19.09 | 19.10 | 19.11 | 19.12 | 19.04 | 19.09 | 19.11 | 19.11 | 19.12 | 19.12 | 19.11 |

Table 3. Monthly mean values of colour of the sea (*F*: Forel's scale), transparency (*D*: m), and plankton volume (*V*: cc/m$^3$).

| Year | Element \ Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1948 | F | — | — | 3.0 | — | 4.0 | 3.1 | 3.3 | 2.2 | 2.5 | 3.0 | 2.9 | 3.4 |
| | D | — | — | 22.0 | 11.0 | 11.5 | 14.0 | 21.3 | 25.4 | 23.5 | — | 17.4 | 19.4 |
| | V | — | — | — | — | — | — | — | — | — | — | — | — |
| 1949 | F | 3.0 | 2.9 | 3.2 | 3.3 | 3.5 | 3.1 | 2.5 | 2.3 | 2.0 | 3.0 | 3.0 | 3.5 |
| | D | 20.9 | 20.6 | 22.0 | 17.8 | 12.6 | 15.5 | 21.5 | 26.2 | 28.3 | 25.5 | 20.8 | 24.0 |
| | V | — | — | — | — | — | — | — | — | — | — | — | — |
| 1950 | F | 3.6 | 3.0 | 3.5 | 4.7 | 3.2 | 3.0 | 2.5 | 2.0 | 2.0 | 3.9 | 2.8 | 2.7 |
| | D | 27.0 | 24.2 | 21.1 | 12.8 | 14.7 | 18.0 | 25.6 | 31.2 | 30.8 | 19.4 | 20.1 | 20.7 |
| | V | — | — | 1.8 | 1.2 | 3.5 | 2.3 | 1.3 | 1.2 | 0.8 | 1.4 | 1.2 | 1.1 |
| 1951 | F | 3.0 | 2.6 | 2.7 | 2.0 | 4.0 | 3.5 | 2.3 | 2.3 | 3.0 | 3.0 | 3.2 | 2.6 |
| | D | 27.0 | 29.4 | 17.8 | 22.8 | 17.2 | 16.0 | 23.8 | 26.6 | 26.4 | 22.0 | 22.0 | 28.8 |
| | V | 0.3 | 0.3 | 2.2 | 0.9 | 2.0 | 3.7 | 2.9 | 0.8 | 0.7 | 0.9 | 0.8 | 0.4 |
| 1952 | F | 2.0 | 2.5 | 2.9 | 3.4 | 3.8 | 3.0 | | | | | | |
| | D | 20.0 | 25.6 | 23.9 | 20.0 | 16.6 | 19.9 | | | | | | |
| | V | 0.1 | 0.4 | 0.8 | 1.5 | 3.4 | 2.9 | | | | | | |

# A CURRENT METER USING A PHOTOTUBE

T. NAN'NITI

Meteorological Research Institute, Tokyo

1. *Physical Principles and Details of the Design.* The current meter is shown in Figs. 1 and 2. $C_1$ and $C_2$ in the figures are brass cases, each with a glass window $GW_1$ or $GW_2$, and the inner parts are kept water tight though water freely passes through between the glass windows. Light of constant intensity is emitted from a light source $LS$, reflected by a cylindrical mirror $CM$ and produces a photo-electric current in a phototube $PT$. $A$ disc $D$ with holes which rotates in accordance with the speed of water current by means of a propeller $P$ is placed in the path of light between the light source $LS$ and the mirror $CM$. Therefore, intermittent light is

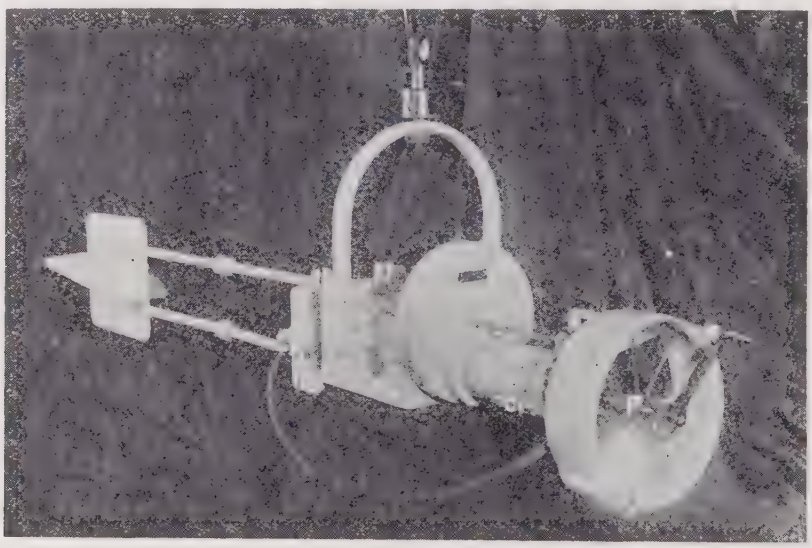


Fig. 1. Under water portion of current meter.

produced by the rotating disc $D$, the frequency of the flash being exactly proportional to the speed of the oceanic current. Consequently, the speed of current can be measured from the frequency of flash. The shape of the mirror $CM$ is an equilateral triangle, more exactly a trapezoid, rolled around a cyclinder like a belt. The cylinder is fitted with a magnet at the bottom, which keeps it in constant direction to the geomagnetic co-ordinate. The light is narrowed by a slit $S$ and forms a line light, and it swivels with the direction of water current, so light of a certain intensity, reflected

by the triangular mirror in accordance with the current direction. Therefore, the current direction can be known also from the measurement of the intensity of the reflected light. However, if the extinction coefficient of water between the glass windows

Fig. 2. Inner part of current meter shown in Fig. 1.

varies during an observation, the intensity of light upon the mirror will be altered, and it causes an error in the observed values of the direction of the current. In order

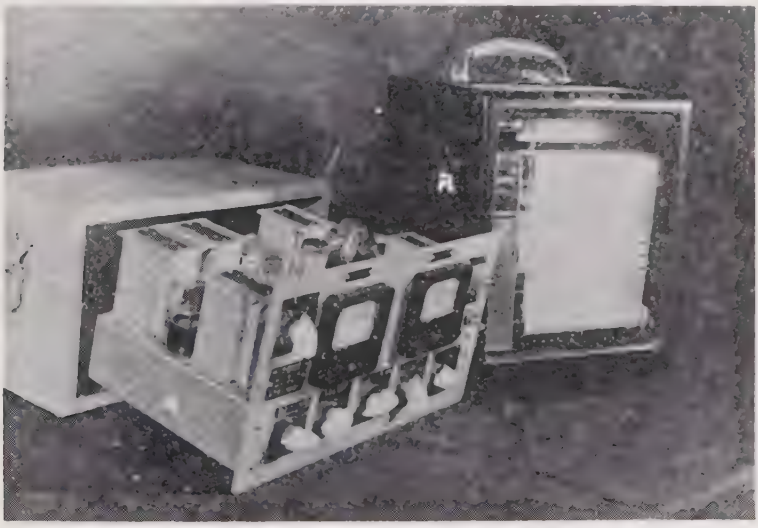


Fig. 3. Amplifier and Recorder.

to avoid this error, two electric coils, $EC_1$ and $EC_2$ are set respectively parallel and normal to the principal line of the instrument. By these coils, four kinds of electro-

magnetic fields, each differing 90° in direction from one another, can be formed. Therefore, relation between the intensity of photoelectric current and the direction of the instrument can be readily recorded on the chart, and as a linear relation exists between the photoelectric intensity and the direction of the instrument (see the following section), the direction of the water current can be determined, irrespective of the intensity of incident light of the mirror.

Next, the photoelectric current is amplified by a vacuum-tube UZ-6C6 and then led to a microammeter on deck by a cable. It is further amplified by means of modulation and led to a recording milliammeter. The amplifier $A$ and the recorder $R$ are shown in Fig. 3. Yokogawa's recording milliammeter, type KR-3, was used, in which the chart is rolled with a speed of 2 cm/min.

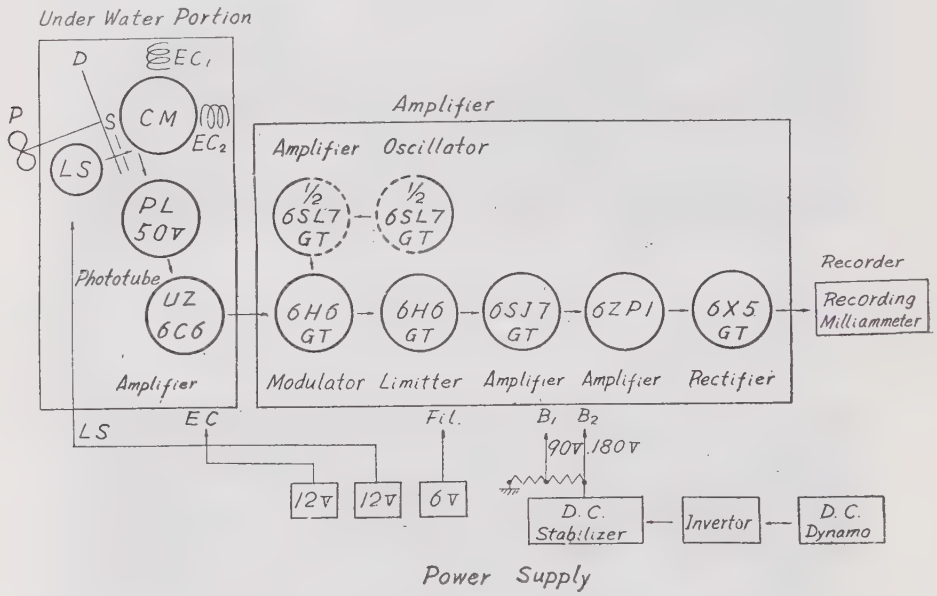



Fig. 4. Schematic block diagram of the instrument.

The schematic block and circuit diagram of the photoelectric measurement process are shown in Figs. 4 and 5.

The relation between the grid bias voltage and the plate current of the vacuum-tube UZ-6C6 is shown in Fig. 6, and the relation between the plate current and the resultant recording current is shown in Fig. 7. The lines in the figure will be changed by the values of noise limitter volume and output current regulator. From the facts shown in Figs. 6 and 7, adjustment of the instrument to the linear relation between the photoelectric current and the recording current is found to be possible.

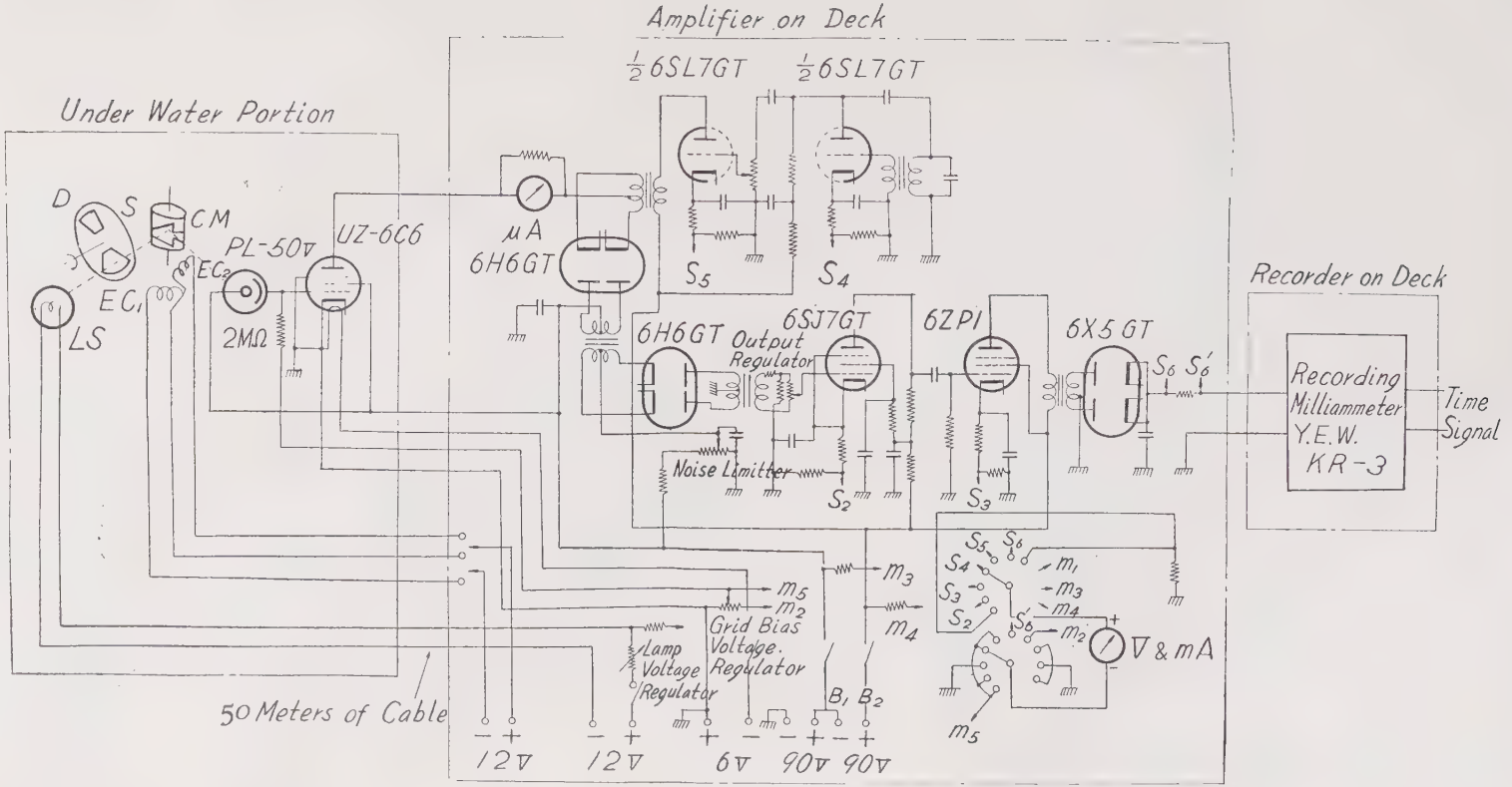



Fig. 5. Schematic circuit diagram of the instrument.

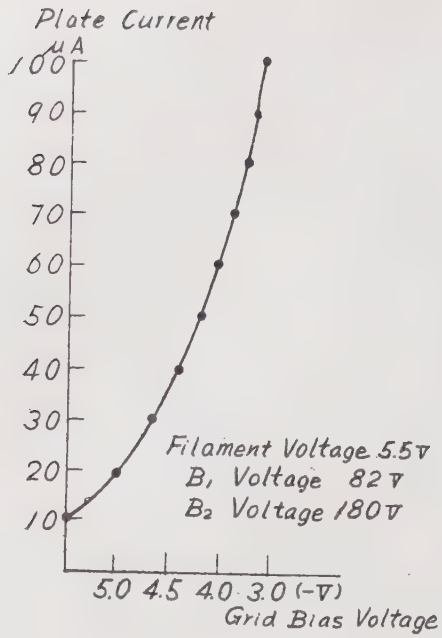



Fig. 6. Relation between the plate current and the grid bias voltage.

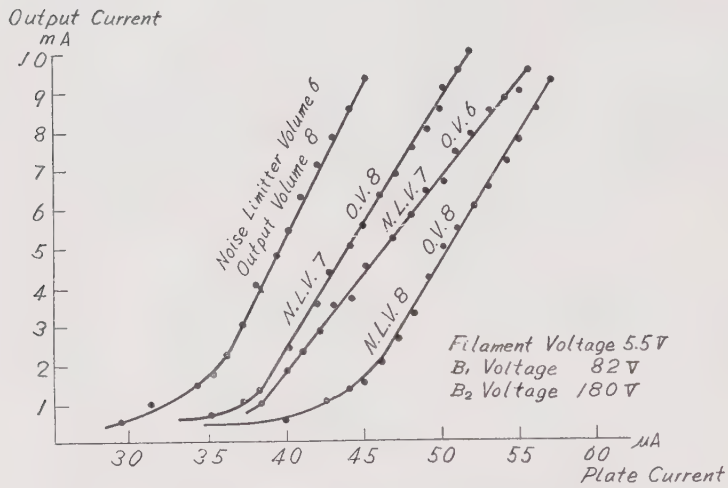



Fig. 7. Relation between the output and the plate current.

2. *Theoretical Consideration.* Now, let the current speed be $v$ cm/sec and the number of flash of light be $n$ time/sec, then we have

$$v = an^2 + bn + c$$

where $a$, $b$ and $c$ are constant. Two holes are made in the disc, which turns one cycle as the wate runs 20 meters. Therefore, the light path opens once per 10 meters movement of water. As it requires $t$ sec and $l$ cm of chart length to record $N$ times of intermittent photoelectric current, then we have

$$n = \frac{N}{t} = \frac{N}{30\,l}$$

So we have

$$v = a\left(\frac{N}{30\,l}\right)^2 + b\left(\frac{N}{30\,l}\right) + c\,.$$

Next, let the breadth of the slit $S$ be $B$, and the vertical length of the mirror $CM$ be $\alpha\theta+\beta$, $0° \leq \theta \leq 360°$, where both $\alpha$ and $\beta$ are constant, and $\theta$ is the angle around the axis of the cylinder. The intensity of light reflected by the mirror is then given by $I_0 e^{-kz}\rho B(\alpha\theta+\beta)$, where $I_0$ is the intensity of original light, $k$ is the combined extinction coefficient of the glass windows and the water, $z$ is its optical path and $\rho$ is the albedo of the mirror. So the photoelectric current $i$ will be proportional to the angle $\theta$, that is $i = K\theta$. From the above figs. 6 and 7, we expect the linear relation between the recording electric current and the direction of the instrument. Indeed, for example, it is seen in Fig. 8.

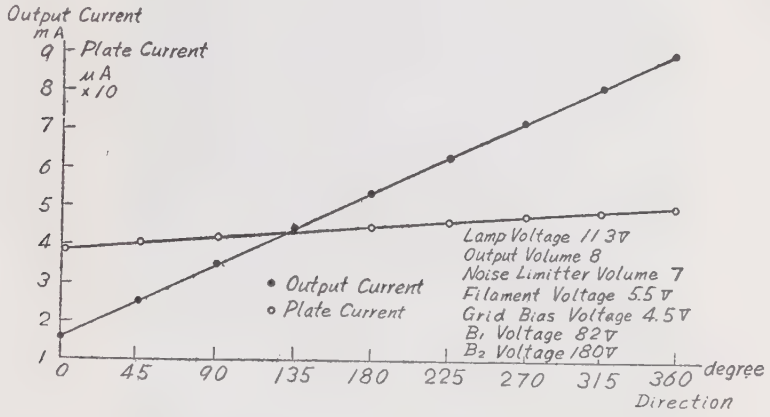



Fig. 8. Relation between the direction of the current meter and the intensity of the photoelectric current.

3. *Experimental Results.* Experiments were performed in Tokyo Bay on board the research ship "Asasiwo Maru" on June 26th and September 17th, 1952. The results are compared with these obtained by the Ekman-Merz current meter, and the new current meter is better than the old one in the respect that it can record the oceanic current more minutely and accurately. For instance, we can see even the fluctuation of oceanic current in Fig. 9, of which amplitude and period are about 40° and several minutes, respectively. The main current direction was S 30°W, the speed being 27.5 cm/sec.

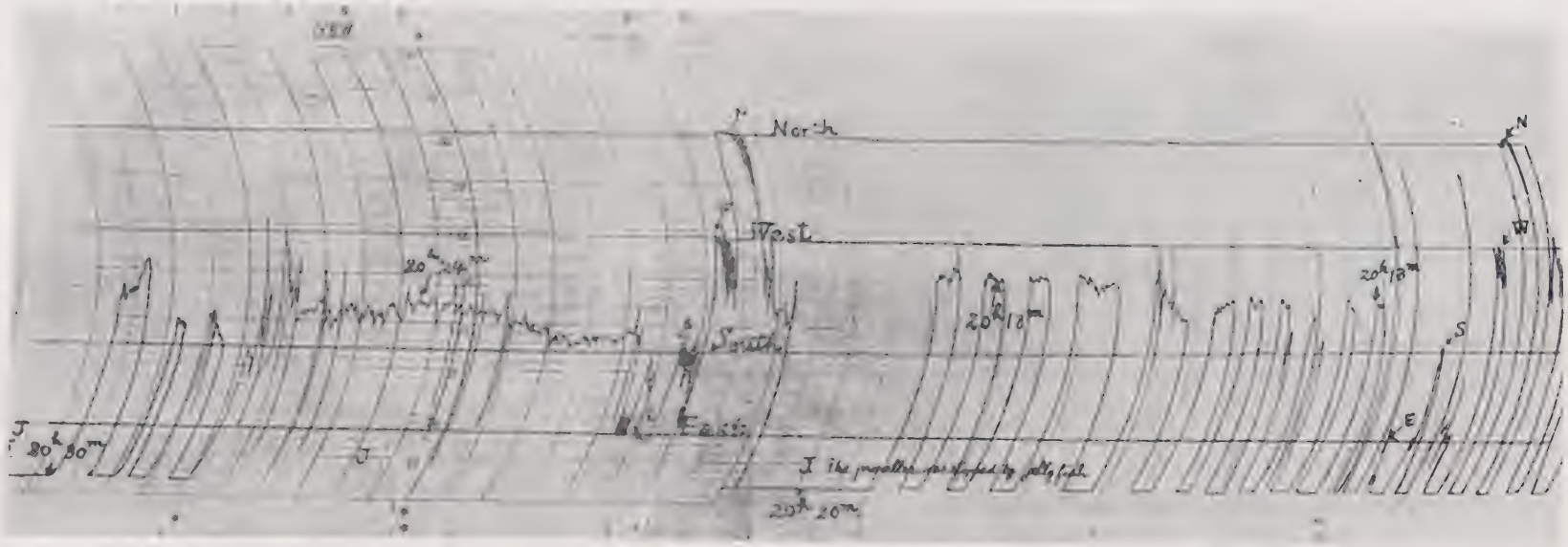



Fig. 9. A record of current obtained at a 1.75 m layer. Note the fluctuation in both speed and direction, and the minute fluctuation in the latter which seems to be caused by vortices. (The width of the chart paper is 12 cm)

*Acknowledgement.* The author wishes to express his hearty thanks to Dr. Y. Miyake and Dr. Y. Takenouti for their encouragements, to Mr. K. Kawamura for his kind advice, and also to the members of the Oceanographic Division of the Central Meteorological Observatory for their help during the observations. His thanks also due to the members of the Toho Denki Co. and of the Turumi Seiki Co. for the construction of the instrument. This work was made possible by a grant for research for test manufacture in 1951 from the Ministry of Transportation.

*References*

T. Nan'niti: A Current Meter using a Photocell. Umi-to-Sora **25**, 5 (1947). (in Japanese)
T. Nan'niti: A Current Meter using a Phototube. Papers in Meteorology and Geophysics MRI. **3**, 4 (1952).

# "KUROSHIO," UNDERSEA OBSERVATION CHAMBER

N. INOUE,* T. SASAKI** and R. OAKI***

1. *Process of the Work.* In 1948 one of the authors, Inoue, conceived from a suggestion of Dr. U. Nakaya, Professor of Hokkaido University, the idea of constructing an instrument by which the investigators would be able to make visual observation under the surface of the sea. The first design of the instrument was made by him and his colleague Oaki in 1949, referring to Dr. W. Beebe's "bathysphere."[1] Prior to setting out to work on this problem some experiments in under-water visibility and photography were carried out by Inoue and another colleague Sasaki during the year 1950. It was very difficult for the authors to develop such an expensive plan as constructing the undersea chamber at that time in Japan. Fortunately it became possible to commence the actual plan in June, 1951, through the financial aid of various agencies; thereupon, in cooperation with about thirty scientists and technical experts, the executive committee for the present work was organized.

The hull was constructed by Tsurumi Shipyard, Nippon Steel Tube Co., according to the design of Oaki, and glass, underwater light, gauges and instruments were

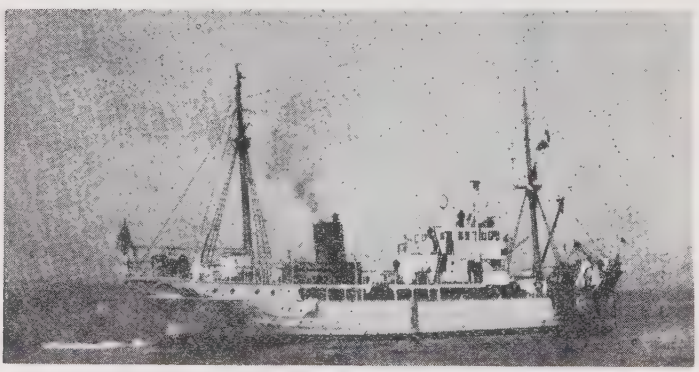


Fig. 1. The mother ship "Oshoro-maru," Training Ship of Faculty of Fisheries, Hokkaido University, with "Kuroshio" hanging on her starboard side.
photo by S. Motoda

* Faculty of Fisheries, Hokkaido University, Hakodate
** Group of Marine Resources Research, Scientific Research Institute.
*** International Marine Engineering Co., Ltd.

designed by the members of the Sasaki Laboratory of Scientific Research Institute in cooperation with other firms. All these were completed in August of the same year, and thirty-two diving experiments, using the Training Ship "Oshoro-maru" (617tons) (Fig. 1) of the Hokkaido University, were carried out in Sagami Bay and Tsugaru Strait between June and December. The outline of these experiments has been previously reported.[2]

In 1952 through the financial support of the Fishery Agency of the Ministry of Agriculture, various improvements on the body and equipment were made, and the diving observations were carried out in the T. S. "Oshoro-maru" around the Japan coast, i. e. Tsugaru Strait, Mutsu Bay, Toyama Bay, off Tsushima, off Nagasaki, Kagoshima Bay, Inland Sea (Setonaikai), off Kochi, Toba Bay, and Sagami Bay, 130 times in all. The work has been accomplished by the assistance of many people, such as the crew of "Oshoro-maru, members of the Sasaki Laboratory and the Inoue Laboratory, who were all engaged mainly in the preparation and manoeuvring; and also by the favours extended by scientists and technical experts of the Regional Fisheries Institutes of the Fishery Agency, Prefectural Fishery Experimental Stations, Hokkaido University, Tohoku University, Kyushu University, Nagasaki University, Mie Prefectural University, Tokyo University, Tokyo Fisheries University, Laboratory of Fishing Craft, Iwanami Moving Picture Producers, and so forth.

2. *Acknowledgement.* The authors are much indebted to the sponsorship of Mr. K. Shibuzawa, Dr. U. Nakaya and other authorities; to Prof. I. Saito and Master T. Fujii of the "Oshoro-maru" and his crew who engaged in operations principally on board the ship, facilitating the work at sea; to Dr. S. Motoda for help in organizing the investigators of various institutes; to Mr. T. Tsujita of the Seikaiku Regional Fisheries Institute; to Mr. T. Kuroki of the Kagoshima University, and to other persons for their kindness in making tbe present work possible.

They also owe deep gratitude for their financial support to the Fishery Agency of the Ministry of Agriculture, Ministry of Education, Hokkaido Prefectural Government, Aomori Prefectural Government, Yomiuri-Shimbun Co., Nippon Steel Tube Co., Taiyogyogyo Co., Nihonsuisan Co., Nihonreizo Co., Nichirogyogyo Co., Kyokuyohogei Co., Nichibeisuisan Co., Nihon-Hoso-Kyokai (N. H. K.), Hokusei-Sempaku Co., Japanese residents in Chicago, several fisheries companies in Nagasaki, and many other agencies.

3. *Construction of the Vessel.*

(i) *General Description:* The vessel is intended to be suspended from a

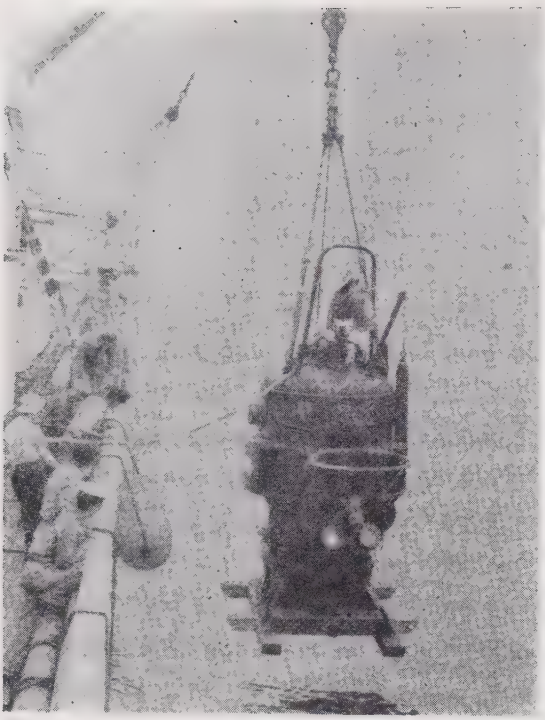


Fig. 2. The external form of the "Kuroshio."
photo. by T. Miura

mother ship and operated by the latter. A continuous underwater observation down to 200 m, with the chamber either stationary or in transit, is made possible with instrumenst and apparatus for the oceanographic and biological measurements and studies. Absolute safety is the fundamental requirement, and sufficient precautions have been taken concerning the strength and watertightness of parts and emergency systems (Fig. 2).

(ii) *Principal Particulars:*

*Dimensions, etc.*

| | | |
|---|---|---|
| Height (to the top of the hatch cover) | | 3.15 m |
| Length (from the tip of wooden bearer to the end of the direction stabilizer fins) | | 3.70 m |
| Diameter of the observation chamber (outside) | | 1.48 m |
| Height of the observation chamber | | 2.20 m |
| Safe diving depth (sea water) | | 200 m |
| Diam. of the suspending wire rope | | 20 m |
| No. of complement | | 2-4 persons |
| Endurance | 2 persons | 10 hours |

*Weight and Buoyancy*

| *Item* | *Weight* | *Buoyancy (sea water)* |
|---|---|---|
| Observation chamber | 3060 kg | 3690 kg |
| Crew and consumables, etc. | 120 kg | —— |
| Suspending wire rope | 300 kg | 32 kg |
| Electric cables | 240 kg | 120 kg |
| sub total | 3720 kg | 3842 kg |

| | | |
|---|---|---|
| | | excess buoyancy 122 kg |
| Bed frame | 720 kg | 350 kg |
| Ballast | 0–800 kg | 0–105 kg |
| Grand Total | 4440–5240 kg | 4192–4297 kg |
| | Excess of weight (negative buoyancy) | 248–943 kg |

*Principal Equipment:*

Main observation window with controllable reflector $1 \times 150$ mm diam.

Aux. observation windows (side and rear) $3 \times 100$ mm diam.

(bottom) $2 \times 100$ mm diam.

Peep hole $1 \times$ 60 mm diam.

Projectors $1 \times 500$ W immersible bulb type, controllable.

$1 \times 500$ W spot light in water-tight case.

$2 \times 25000$ lumen-seconds Strobo-flash lamps in water-tight cases.

Several immersible 100 W bulbs.

Communication instruments; 1 Telephone, 1 Teletalk.

Turning gear 1 set, Emergency releasing gear 1 set, Water sampler 1 set, Mud sampler 1 set, Oxygen feeder 1 set, $CO_2$ absorbing unit 1 set, Ventilating system 1 set, Braun tube type echo-sounder 1 set, Hydrophone 1 set, Camera holders (adjustable) 2 sets, Miscellaneous gauges. Marker buoy and emergency hauling system.

(iii) *Principal Features of the hull and equipment* (Figs. 3 and 4).

*Hull* The hull consists of an observation chamber and a bed frame and of all the welded parts.

The observation chamber is pivoted to the bed frame and can be revolved around the latter through a lack and pinion device, and the pivot is capable of being released in an emergency. The chamber, a barrel shaped body constructed of mild steel plate and cast steel, is designed to maintain a safety factor of not less than 2, based upon the calculated collapsing pressure, allowing sufficient margin for the expected irregularity of the cross-sectional shape in welding.

The bed frame is a seat with wooden bearer and two direction-stabilizing fins of large aspect ratio to follow a flow of low speed.

A horizontal rudder fitted between the stabilizer fins is intended to adjust the dip of the vessel in contour diving.

The total negative bouyancy can be adjusted by means of removable cast iron ballast blocks.

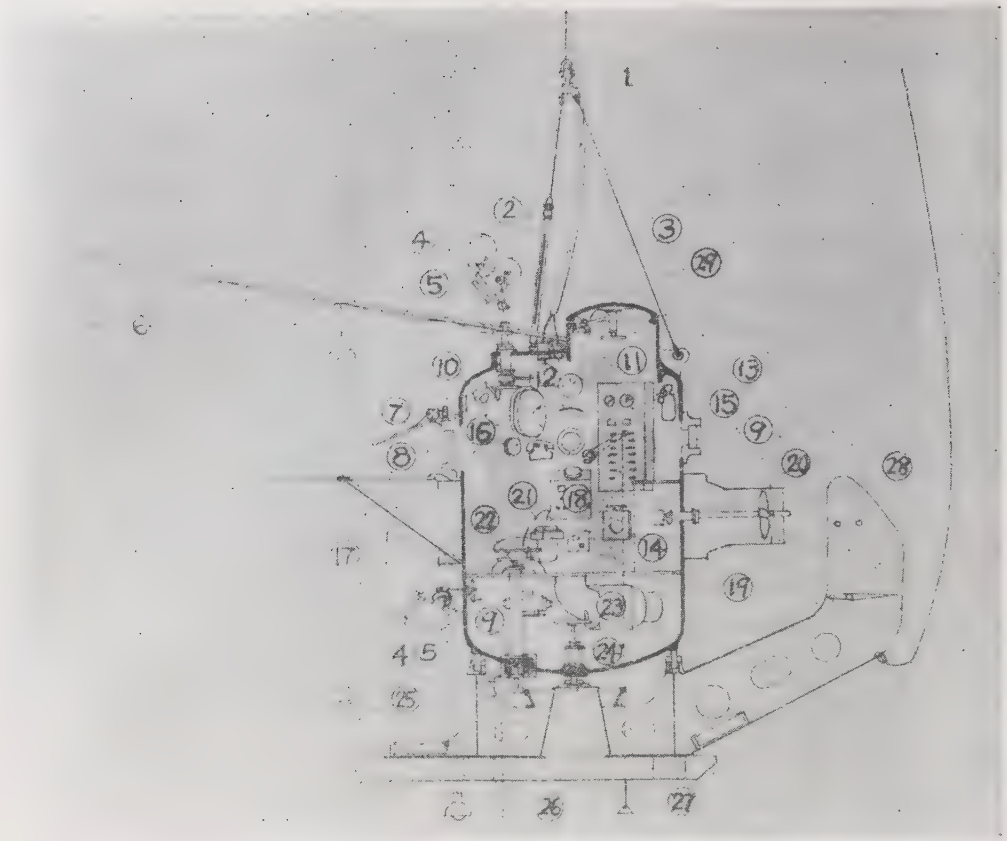


Fig. 3. Schematic diagram of "Kuroshio"

1. Swivel Piece 2. Sling (Adjustable) 3. Main Cable and Telephone Line. 4. Strobo Flash Lt. 5. Projector 6. Portable Lt. 7. Back Mirror 8. Main window 9. Aux. Window 10. Teletalk 11. Clock 12. Clinometer 13. Switchboard 14. Auto-Trans. 15. Oxygen Feeder 16. Depth Gauge 17. Fish Catcher 18. Echo-Sounder 19. Hydrophone 20. Propelling Apparatus (not in use) 21. Gyro-Compass 22. Turning Gear 23. Ventilator and $CO_2$ Absorber 24. Emergency Releasing Gear 25. Ballast (Removable) 26. Mud Sampler 27. Water Sampler 28. Buoy Rope 29. Hatch

Fig. 4. The inside view photographed from the hatch of the "kuroshio"
photo. by S. Sugimoto

The inner surface of the observation chamber is cork-painted white to prevent dewing, the outer hull being painted dark blue.

The hatch has a clear opening of 450 mm diam. and can be readily opened or closed from inside or outside.

The suspending wire has a swivel

piece with ball bearing at the lower end to allow free revolving of the chamber, and adjusting screws fitted in the sling are intended to adjust the dip of the chamber.

*Observation windows.* The frames are of substantial cast steel and provided with removable blind plugs inside. The lenses are specially composed of flat, heat treated tough glass of two tiers glued together, each sheet being guaranteed, through carefuly conducted experiments, to withstand the external pressure of 1000 meters depth (Fig. 5).

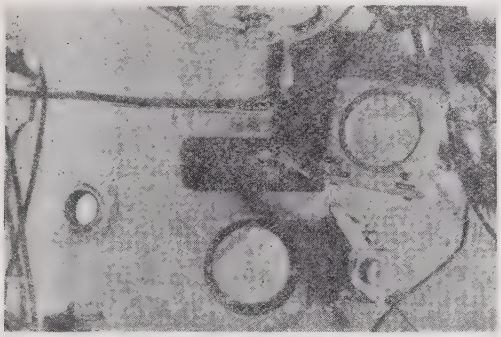


Fig. 5. The view near the main observation window inside the "Kuroshio" photo. by S. Sugimoto

The main front window is provided with a back mirror 300 mm × 400 mm in size controllable from inside allowing vision in any direction.

*Fish Catcher.* A series of fish attraction lamps and a net suspended in front of the chamber are intended for the purpose of catching young fish.

*Water sampler.* A 6 mm diam. brass tube is suspended from the chamber and the height of the suction bell mouth is controllable from inside so that water can be sampled at any required place between 2 metres.

*Mud Sampler.* A perforated thin steel tube can be attached to the bed frame when required.

*Ventilation and $CO_2$ Absorbing System.* A ventilating system equipped with a soundless propeller fan of 30 W and $CO_2$ absorbing unit is installed under the floor of the observation chamber.

*Emergency Life Saving Apparatus.* The guard rope of electric cables has sufficient strength to bear the negative buoyancy.

In addition, a marker buoy rope of the same strength, is fastened to the bed frame, not only to hold the direction of the bed frame, but also to be the second emergency hauling line.

Even when all the hauling systems are disabled, the observation chamber is able to float by abandoning the bed frame.

*Power Unit.* Power supplied from the mother ship is 200 volt, 50 cycle, single phase A. C., delivered to projectors, gyro-compass and room light. An auto-

transformer of 1 KW capacity installed in the chamber supplies 80-110 volt A. C. to other instruments.

*Electric Cables.* The main cable is a two core 8 square mm cabtyre, and the communication cable is a 2 square mm five core shielded rubber cord. Both are wrapped together with a guard rope of steel wire sheathed in canvas.

The hull penetration is kept watertight by double glands with graphite asbestos packing.

*Projectors.* The upper unit (a 500 W immersible main projector and a strobo-flash unit) can be elevated or revolved from inside, and the lower (a 500 W spot light and a strobo-flash) can be controlled from inside.

In addition, three 100 W portable immersible bulbs can be suspended anywhere required.

The room light is a 40 W wall lamp.

*Teletalk and Telephone.* Besides an ordinary telephone system, an interphone system is installed with a sub-unit in the chamber and a master unit on board the ship.

*Hydrophone.* One set of Rochel-salt type hydrophones is fitted in front of the chamber.

*Echo-Sounder.* A Braun tube type echo-sounder of 40 kc with two transducers, one horizontal and the other vertical, readily convertible, is provided.

*Gauges and Miscellaneous Equipment.* An electric gyro compass of simple construction with a motor generator and other accessories. Two Bourdon's tube type depth gauges. One Aneroid barometer. Two bent glass tube clinometers. One Marine clock. One oxygen feeder unit.

(iv) *Result of Tests and Trials.*

*The observation chamber* was tested with external pressure of 25 kg/cm$^2$ at the yard, and the completed vessel without crew was immersed down to 220 meters prior to the operation at sea. The results were satisfactory except for some leakage in the junction jacks of the cables.

*The effect of humidity upon the electric instruments* was rather serious, especially in summer. Dehumidifying with silica-gel proved to be inefficient, and silicon-resin water proof grease also was not quite satisfactory. The only way was to enclose every junction in an air-tight box.

*The Communication Cable.* Owing to the lack of mechanical strength, the core wires were often broken with severe handling.

The shaft penetrations had been water-proofed inside double glands, each generally with 3 tiers of fatty cotton packing, but a single gland with 4 tiers of packing also proved to be satisfactory.

(v) *Further Amendments Suggested.*

*Observation Windows.* Visual range through a clear diam. of 150 mm. is not sufficient, even with the aid of the reflector apparatus, and lens material with more strength and optical homogeneity must be provided.

An obliquely projected window is to be installed to obtain a wider angle of vision downward.

*Electric Cables.* A mechanical handling device for the cables and ample strength of the cable itself for the grueling service are to be provided.

A co-axial armoured cable, like a submarine cable, may be preferable.

*Revolving Gear.* It is to be of the self-locking type.

4. *Operation at Sea.* The "Kuroshio" is hung down along the outside of the hull of the mother ship "Oshoro-maru" by means of a steel wire pulley on the end of a derrick. The lowering and raising are done by an electric motor winch (this can be changed to a steam winch when the former is damaged) usually at a speed of about 20 metres per minute.

Before the "Kuroshio" is manned by observers, the air inside the observation room is perfectly cleaned by blowing the compressed air jet. Although equipped with the oxygen feeder and $CO^2$ absorber, a blow of the fresh air is sufficient for one hour for three observer without operation of the above air-cleaner.

The descending and ascending "Kuroshio" is watched by an echo-sounder on the bridge of the mother ship and, moreover, the descent is made with safety by measuring the distance between the "Kuroshio" and the sea bottom with the Kuroshio's own echo-sounder. The communication between the bridge of the ship and the "Kuroshio" is continuously maintained by either telephone or interphone, making possible the careful operation of descent and ascent.

The suspended "Kuroshio" is usually slowly propelled by the drifting or slowly moving mother ship, but it is dangerous for the "Kuroshio" to move close to the rocky or steep bottom. However, when the mother ship can be anchored, the bottom

observation is possible by settling the "Kuroshio" itself on the bottom, though the setting of ship accurately at the desired position requires great skill.

5. *Some Observation made in 1952.* Below the surface suspended materials like snow flakes were observable everywhere to the naked eye when they came into the beam produced by the projector light outside the chamber (Fig. 6). According to the laboratory experiments of Suzuki and Kato[3] of the Hokkaido University, these suspended flakes are assumed to be the aggregates of disintegrating corpses of planktonic minute organisms. These unidentifiable masses should be named "marine snow" (Suzuki and Kato) or "sea snow" or "plankton snow" (Motoda), and resemble light scattering objects shown by Emery[4](1952, Fig. 7).

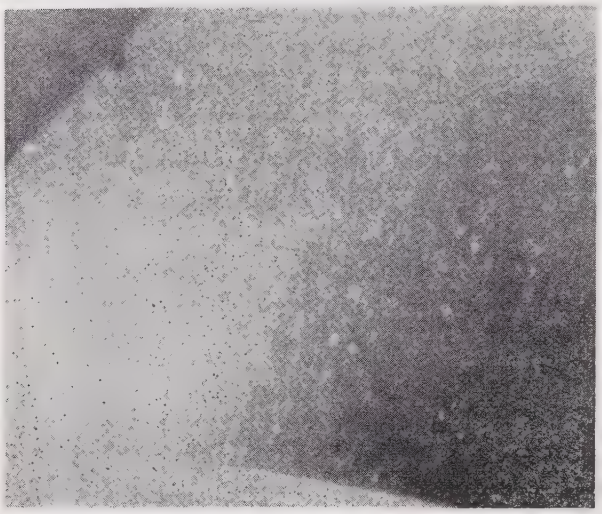


Fig. 6. The "Marine snow" suspended materials like snow flake below the surface
photo. by S. Sugimoto

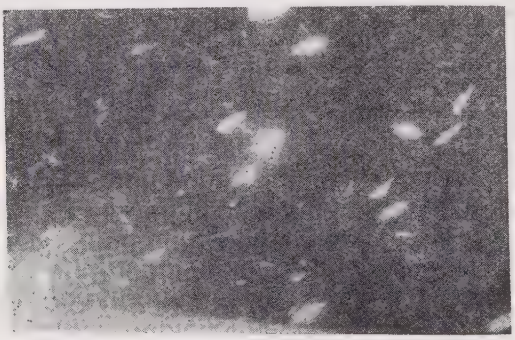


Fig. 7. The horse-mackerels 20 metres under the surface in the Tachibana Bay near Nagasaki
photo. by S. Sugimoto

The authors and other observers have often experienced seeing very turbid water near the shallow bottom, while the upper water was comparatively transparent. In such cases the suspended flakes were very dense near the bottom. In the deep, say 100 metres and over, they have tended to become smaller and visibility was good.

There appeared large swarms of fry in Tsugaru Strait in October, and they remarkably crowded about when the light was turned on. Horse-mackerels were visible near Nagasaki in November (Fig. 7), and at the same time their swarm was distinctly recorded by the echo-sounder of the mother ship. The sea bottom was clearly observed in various areas when the water was transparent; also sometimes the

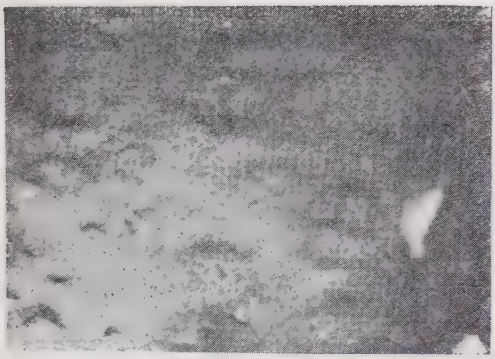


Fig. 8. The sea bottom inhabited by sea-pen at 124 metres depth, photographed through the back mirror of the "Kuroshio" in the Sagami Bay. Piles made by bottom animals appeared.
photo. by S. Sugimoto

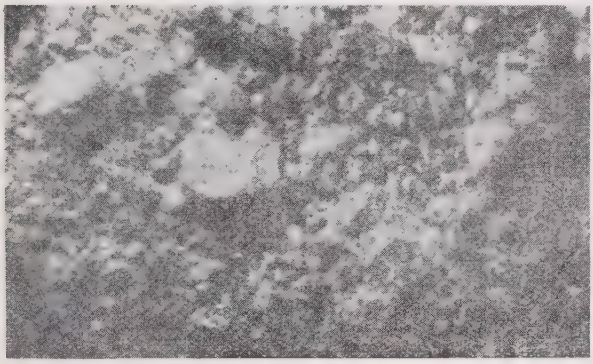


Fig. 9. A culture bed for ärkshell 17 metres under the surface in Mutsu Bay
photo. by S. Sugimoto

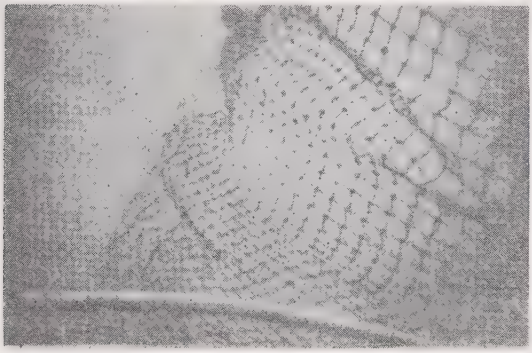


Fig. 10. A part of the medium trawlnet under operation at 24 metres depth off Kushikino in Kagoshima Prefecture. photo. by S. Sugimoto

bottom fish and benthic animals, such as sea-robin, starfish, gorgonias, shrimps, polychaetes, clams, sea pen, sea anemones, etc., were observed. Their burrows and piles also were seen (Fig. 8). The photograph of a culture bed for ärkshell in Mutsu Bay is shown in Fig. 9.

Ripples probably produced by a bottom current were found on the bottom as deep as 100 metres in Tsushima Strait. Near Hashima Island off Nagasaki the investigation was carried out at the sand stone bottom where a coal bed was expected to be exposed.

The battleship "H. M. S. Mutsu" which exploded and sank in June, 1943, in the Inland Sea, was also brought into the focus of the present observation. Here, as the mother ship, the wooden crane-boat "Otorimaru, No. 8" was chartered to avert danger of submarine magnetic mines laid during the war. The "Kuroshio" was suspended down along the side of the hull of the wreck, and the view of the broken hull inhabited by fish was photographed.

At the request of Taiyogyogyo Co., Nagasaki, the shape of a medium trawlnet under operation was confirmed by diving observation (Fig. 10).

In October a migrating swarm of squid (Ommastrephes sloani pacificus) appeared in sight of the "Kuroshio" and the sound made by them was recorded by hydrophone equipment.

*References*


[1] Beebe, W., 1943. Half Mile Down.

[2] Inoue, N., T. Sasaki and R. Oaki, 1952. Journ. Scient. Res. Inst., Vol. **46**, pp. 147–161.

[3] Suzuki, N. and K. Kato, 1953. Preliminary notes of chemical studies on suspended materials, "marine snow," in sea water. Bull. Fac. Fish. Hokkaido Univ., Vol. **4**, No. 1 (in press).

[4] Emery, K. O., 1952. Submarine photography with the benthograph. Sci. Month., Vol. **75**, No. 1, pp. 3–11.

# ON THE EFFECT OF WAVES UPON THE VERTICAL DISTRIBUTION OF WATER TEMPERATURES

T. ICHIYE

Kobe Marine Observatory.

1. It is commonly regarded that the subsurface layer is disturbed by the wave action and that a homogeneous layer is formed near the surface of a rough sea. A qualitative investigation of this problem has been treated by the German oceanographers P. Bintig[1] and J. Richter[2], who discussed the relation between the wind velocity and water temperature in the eastern North Atlantic, Bay of Biscay and the North Sea, respectively and found that the water temperatures fall with the increasing wind force in summer due to the mixing with cooler water from below. Here the author has determined the relation between the state of sea and the differences of subsurface water temperatures from the surface ones $T_0-T_{10}$, $T_0-T_{25}$, $T_0-T_{50}$, where $T_0$, $T_{10}$, $T_{25}$, $T_{50}$ mean the temperatures at a depth of 0, 10, 25 and 50 meters respectively, from the observations at a fixed point X (N 39°, E 153°) and T (N 29°, E 135°) from 1948 to 1949.

The results are shown in Table 1, where the numbers of samples ($n$), the mean values of these differences ($\bar{x}$), their unbiased estimated variance ($\bar{u}$) and 90% confidence limits of the mean values ($r$) are tabulated according to the different sea states, separately in the summer or stratification season (June, July, Aug. and Sept.) and in the winter (mixing) season (Nov., Dec., Jan. and Feb.).

2. In the former season data are derived from points X and T, and also for the state of sea 1, 2 and 3 only data of X point are shown, whereas in the latter only X point is treated, since the data at T point are scarce. (For the state of the sea 0 and 4, numbers of data are 0 and 2). From this table we can see that in the summer season the temperature differences at each depth clearly show a decrease as the sea becomes high, especially in the $T_0-T_{10}$ zone above the sea state 4, which indicates that the homogeneous layer develops to this depth. $T_0-T_{50}$ also shows some decrease and this is probably due to the fall of the surface temperature by the surface mixing with the deeper waters as the sea state becomes rougher.

The variance $u$ also decreases with the increasing state of sea, which seems to be due to the fact that even when the various kinds of water masses exist near the surface, they are mixed with the surface waters and a homogeneous layer is formed when the sea is rough. The increase of $\bar{u}$ with the depth shows the frequent existance of different kinds of waters below the 50m depth. In the winter season the temperature differences are generally much smaller than in the summer at the depth of 50 m, and from the values of $T_0-T_{10}$ we can conclude that a surface inversion layer develops and its depth increases with the increasing state of the sea from the change of sign of $T_0-T_{25}$. It is also remarkable that the differences decrease also in this season as the sea becomes high, though the rate of decrement is not so conspicuous as in the summer season.

3. In this section the most simple, phenomenological theory about the effect of waves is given, though an interpretation of transport processes from the statistical mechanical stand point is necessary for the complete discussion of this problem and it shall be provided in other papers. The stationary equation of heat transfer near the surface is given by

$$A\ dT/dz = P\,, \qquad (1)$$

where the z-axis is taken vertically upwards and $z=0$ at the surface. Here we assume that the Austausch coefficient $A$ is composed of two parts, one of which is the effect of purely turbulent flow $c$, and the other that of the mixing action of waves, and further we consider that the latter effect has an important role only near the surface layer. If analogy is sought in the mixing theory of Prandtl[3] and a diffusion coefficient is assumed to be $\overline{w'e}$, where the turbulent elements are individual waves, then $l \sim He^{2\pi z/L}$ $u' \sim HL^{-1/2}e^{2\pi z/L}$, where $H$ is the wave height and $L$ the wave length, and we may put the latter part as $Be^{\alpha z}$. Further, the heat flux at the surface is assumed to be constant with the depth, then the difference of temperatures at the depth $z$ from the surface temperatures is

$$T_0-T_z = -\frac{P}{C}\left\{z+\frac{1}{\alpha}\log\left(1+\frac{B}{C}\right)-\frac{1}{\alpha}\log\left(1+\frac{B}{C}\,e^{\alpha z}\right)\right\}. \qquad (2)$$

Here we determine the relations between $\alpha$, $B/C$ and the state of sea $(s)$ from the observed mean values as shown in Table 1. Assuming that $e^{\alpha z} \fallingdotseq 0$ at the depth of 50m, then

$$T_0-T_{50} = -\frac{P}{C}\left\{z+\frac{1}{\alpha}\log\left(1+\frac{B}{C}\right)\right\}\,,$$

and from the analogy with the mixing length theory, we put $B/C = ns^2$, since $B \sim H^2$ and it is reasonable to consider $s \sim H$. When $s=0$, $B=\alpha=0$, then P/C

can be determined immediately as $-0.1188$ (the unit of length is taken as the meter) from the observed value of $(T_0-T_{50})_{s=0}=5.94(°C)$. Then from each value of $T_0-T_{50}$ for a different $s$ we can obtain the relations between $\alpha_k$ and $n$, where $\alpha_k$ is the value of $\alpha$ for the state of sea $k$, as follows:

$$\log(1+n)=2.61\,\alpha_1\,,\quad \log(1+4n)=7.64\,\alpha_2\,,$$
$$\log(1+9n)=10.82\,\alpha_3\,,\quad \log(1+16n)=13.61\,\sigma^4\,.$$

First assuming $\alpha_k=const.$, three values of $n$ are determined from the above relations, the mean of which is 0.127, then again from these equations each value of $\alpha_k$ can be computed, which is

$$\alpha_1=0.051,\quad \alpha_2=0.058,\quad \alpha_3=0.076,\quad \alpha_4=0.083.$$

From this series of $\alpha_k$ the functional relation of $\alpha$ with $s$ becomes $\alpha=0.047\,s^{0.48}$ by the method of least squares.

By use of this relation of $\alpha$ and $B/C$ with $s$ we have calculated the values of $T_0-T_z$ for $z=10$, 25, 50m and shown the results in Fig. 1 as the curves I, the values $(T_0-T_{25})_{s=0}=2.20(°C)$ $(T_0-T_{10})_{s=0}=0.725(°C)$ are taken, since the observed values of these are not consistent with the theoretical relation for the case of $s=0$ and the quantity of data is so scarce that their reliability is somewhat doubtful, and further the aim of the present discussion is only to show the decrease of temperature difference with the increase of $s$. The observed mean values of $T_0-T_z$ are also plotted in this figure and the theoretical curves seem to be in good accord with the observed data in essential points, in spite of the rough assumption about the functional forms of $\alpha$ and $B/C$.

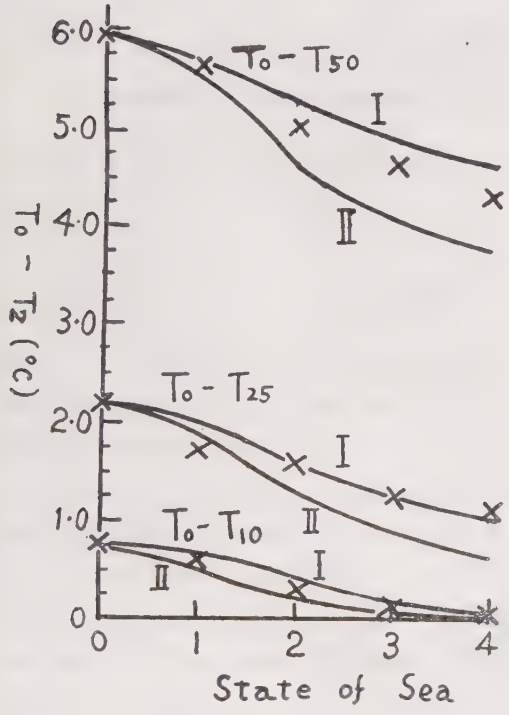



Fig. 1. The theoretical and observed relations between $T_0-T_z$ (°C) and the state of sea in the summer season.
× the observed mean value.
— the theoretical curve.
I for the case $B/C=0.127s$, $\alpha=0.047s^{1.48}$
II for the case $B/C=0.4s$, $\alpha=0.09s^{-1}$
($s$=state of sea, $\alpha$ in $m^{-1}$)

In the above expressions of $\alpha$ and $B/C$ the effect of wave length to the diffusion coefficient is neglected and

from the form of $\alpha$ the effect of wave action is limited more to the surface layer as the sea becomes rough, but it is more reasonable to assume $L \sim s$, since the wave length increases also with the state of sea, thus $\alpha \sim s^{-1}$, $B/C \sim s^{3/2}$. However, from practical calculation of the observed data it is found that the values $\alpha = ms^{-1}$, and $B/C = ns$ are more appropriate and by numerical calculations almost similar to the above method we have obtained the most probable values of $m$ and $n$ as $m=0.09$ and $n=0.4$, where the unit of length is also the meter. The theoretical curves computed by use of these relations are shown in Fig. 1 as the curves II. The agreement with the observed results is not so good at the 50m depth, but the criterion which is more adequate of these two curves is quite difficult, owing to the various assumptions included in the process of the computation.

In the winter season the process of heat transport near the surface layer is somewhat different from summer, and the effect of convection should be taken into account as seen from another paper of the author[4] and the equation of heat transfer is given by

$$DT + (Be^{\alpha z} + C)dT/dz = P \qquad (3)$$

in place of Eq. (1). The solution of this equation is also quite elementary and

$$T = \{P \int_0^z e^{\frac{Dz}{C}} C^{-\frac{D}{\alpha C}} (C + Be^{\alpha z})^{-\frac{D}{\alpha C}-1} + T_0\} e^{-\frac{Dz}{C}} \left(1 + \frac{B}{C} e^{\alpha z}\right)^{\frac{D}{\alpha C}}. \qquad (4)$$

When $B = 0$ it becomes simply

$$T_0 - T_z = (1 - e^{-\frac{D}{C}z}) \left(T_0 - \frac{P}{D}\right) \qquad (5)$$

and from the data in Table 1 it seems to fit approximately to the case of the state of sea 0~1. Therefore we can determine the most obscure quantity $P$ from the more obvious quantities. For such a purpose we take the values $D = -5 \times 10^{-4}$(cm/sec) and $C = 10$ (cm$^2$/sec) from the values given in the paper cited above and further, by use of data for the case of $s=0 \sim 1$ in Table 1 we can obtain $(T_0 - P/D) = 23.6$ (°C) by the method of least squares. Then if we take the mean surface value, $T_0 = 15$(°C), $P = 6.8 \times 10^{-3}$ (degree sec/cm). Thus it should be noted that $P > 0$ in this season, contrary to the summer season, which indicates that the heat flows upwards at the surface, probably due to the intense evaporation, and this causes an inversion layer at the subsurface layer when the sea is rough, as qualitatively seen from equation (4). By use of these numerical constants and the same functional forms for $\alpha$ and $B/C$ as in the curves I, we integrate the Eq. (4) numerically and the results are shown in Fig. 2, where the observed values of $T_0 - T_z$ are also plotted. The agreement of the computed curves and the observed points is not as good as in

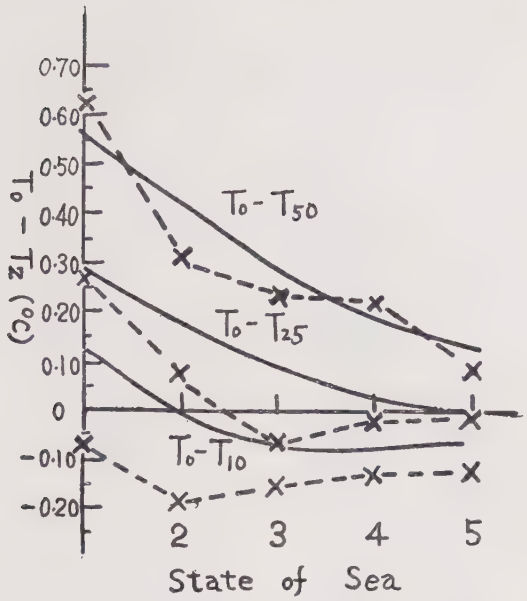



Fig. 2. The theoretical and observed relations between $T_0 - T_z$ (°C) and the state of sea in winter season.
× the observed mean value.
— the theoretical curve.

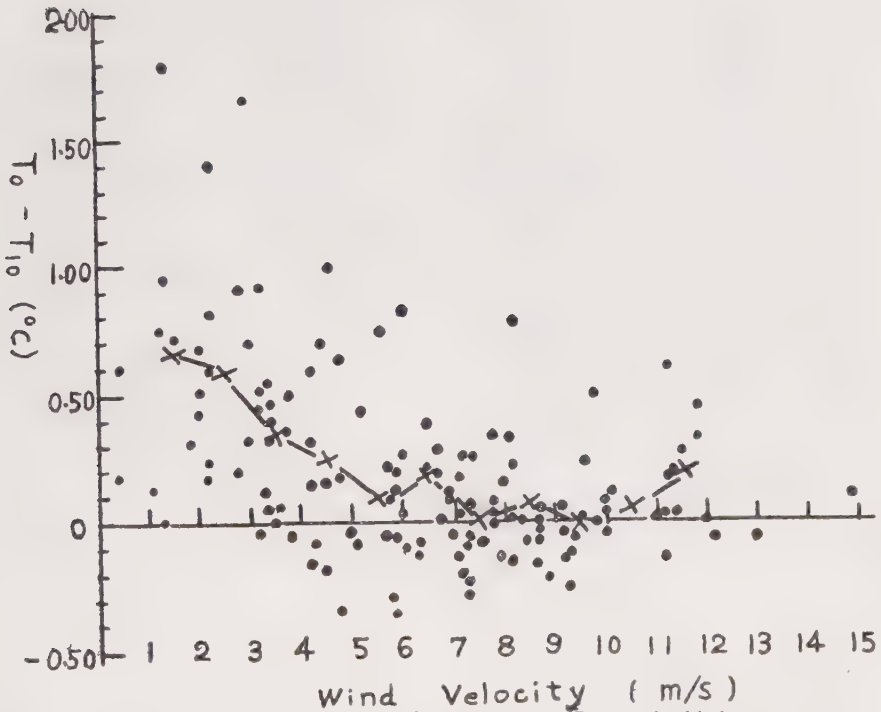



Fig. 3. The relation between $T_0 - T_{10}$ (°C) and wind velocity (m/s) in summer season (June, July, Aug. and Sept.) at the fixed point X.
(× indicates the mean value of $T_0 - T_{10}$ per m/s)

Table 1. Statistical relations of temperature differences and the state of sea.

(1) Summer season (June, July, Aug. and Sept.)

(A) Data derived from X.and T-point.

| State of sea | $T_0-T_{10}$ | | | | | $T_0-T_{25}$ | | | | | $T_0-T_{25}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 |
| $n$ | 6 | 56 | 72 | 66 | 23 | 6 | 56 | 72 | 66 | 23 | 6 | 56 | 72 | 66 | 23 |
| $\bar{x}$ (°C) | 1.325 | 0.573 | 0.285 | 0.127 | 0.063 | 2.20 | 1.70 | 1.60 | 1.23 | 1.13 | 5.94 | 5.63 | 5.02 | 4.65 | 4.32 |
| $\bar{u}$ (°C) | 0.577 | 0.648 | 0.578 | 0.361 | 0.286 | 1.30 | 2.00 | 1.73 | 1.57 | 1.24 | 1.24 | 3.44 | 3.09 | 2.99 | 2.56 |
| $r$ (°C) | 0.518 | 0.146 | 0.114 | 0.075 | 0.104 | 1.17 | 0.45 | 0.34 | 0.32 | 0.45 | 1.12 | 0.78 | 0.61 | 0.62 | 0.94 |

(B) Data derived only from X point.

| State of sea | $T_0-T_{10}$ | | | $T_0-T_{2}$ | | | $T_0-T_{50}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| $n$ | 31 | 43 | 45 | 31 | 43 | 45 | 31 | 43 | 45 |
| $\bar{x}$ (°C) | 0.668 | 0.271 | 0.153 | 2.91 | 2.36 | 1.51 | 7.54 | 7.27 | 5.87 |
| $\bar{u}$ (°C) | 0.713 | 0.683 | 0.386 | 1.86 | 1.41 | 1.69 | 2.52 | 2.71 | 2.35 |
| $r$ (°C) | 0.220 | 0.178 | 0.098 | 0.57 | 0.37 | 0.43 | 0.78 | 0.70 | 0.59 |

(2) Winter season (Nov., Dec., Jan. and Feb.). Data derived only from X point.

| State of sea | $T_0-T_{10}$ | | | | | $T_0-T_{25}$ | | | | | $T_0-T_{50}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0~1 | 2 | 3 | 4 | 5 | 0~1 | 2 | 3 | 4 | 5 | 0~1 | 2 | 3 | 4 | 5 |
| $n$ | 6 | 17 | 41 | 9 | 8 | 6 | 17 | 41 | 9 | 8 | 6 | 17 | 41 | 9 | 8 |
| $\bar{x}$ (°C) | −0.070 | −0.186 | −0.147 | −0.216 | −0.114 | 0.271 | 0.076 | −0.058 | −0.003 | −0.001 | 0.625 | 0.313 | 0.236 | 0.223 | 0.089 |
| $\bar{u}$ (°C) | 0.469 | 0.280 | 0.236 | 0.200 | 0.145 | 0.425 | 0.334 | 0.435 | 0.400 | 0.288 | 0.607 | 0.597 | 0.489 | 0.453 | 0.265 |
| $r$ (°C) | 0.423 | 0.122 | 0.063 | 0.132 | 0.104 | 0.383 | 0.146 | 0.116 | 0.263 | 0.206 | 0.547 | 0.261 | 0.130 | 0.298 | 0.189 |



Table 2. Statistical relations of temperature differences ($T_0-T_{10}$) and wind velocities (X point, summer season)

| Wind Vel. (m/s) | 1~2 | 2~3 | 3~4 | 4~5 | 5~6 | 6~7 | 7~8 | 8~9 | 9~10 | 10~11 | 11~12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $n$ | 7 | 11 | 17 | 13 | 13 | 13 | 17 | 14 | 10 | 4 | 10 |
| $\bar{x}$ (°C) | 0.67 | 0.57 | 0.33 | 0.25 | 0.08 | 0.22 | 0.01 | 0.07 | 0.00 | 0.05 | 0.20 |
| $\bar{u}$ (°C) | 0.95 | 0.88 | 0.19 | 0.20 | 0.06 | 0.07 | 0.01 | 0.06 | 0.02 | 0.01 | 0.09 |
| $r$ (°C) | 0.75 | 0.50 | 0.19 | 0.21 | 0.13 | 0.13 | 0.03 | 0.11 | 0.09 | 0.12 | 0.19 |

the case of summer, but the general tendency of both is similar, which indicates that the effect of waves is not so much different, whether the convection exists or not.

4. The relation of temperature difference and wind velocity is also investigated, but here only the case of $T_0 - T_{10}$ in the summer season at the point is shown graphically in Fig. 3, where the values of $T_0 - T_{15}$ are plotted against the wind velocity in m/sec. Further, the same statistical quantities as the above case obtained from this data are shown in Table 2. Detailed discussions on these results are avoided, but it is generally seen that the temperature differences and their variance decrease with an increase in the wind velocity in accordance with the case of the relations with the state of sea, as expected from the fact that the state of sea becomes rough with the increasing wind velocity.

Lastly, the author wishes to express his thanks to Mrs. Chiyoko Ichiye for the arrangement of data and calculation.

*References*

[1] P. Bintig. Der Einfluß des Windes auf die Wassertemperaturen des Ozeans und ihr Zusammenwirken mit der Lufttemperatur. **I** u. **II**. Ann. d. Met. 3. Jahrg. 7/8 u. 11/12., 1950.

[2] J. Richter. Über den Zusammenhang zwischen Windstärke und Wassertemperatur in der Nordsee. Ann. d. Met. **4**. Jahrg. 7/9., 1951.

[3] T. Ichiye. A Short Note on the Suspension of Particles by the Wave Action. Mem. Kobe Mar. Obs. Vol. **9**, 1951.

[4] T. Ichiye. On the Annual Variation of Water Temperature. Mem. Kobe Mar. Obs. Vol. **10**, 1950.

# ON THE HYDROGRAPHIC CONDITIONS OF THE SEA OF JAPAN IN SPRING AND SUMMER 1949

Abridged from the Journal of the Oceanographical Society
of Japan Vol. 6, No. 4 (1951)

I. YAMANAKA

Japan Sea Regional Fisheries Research Laboratory, Niigata

A number of reports have been published on the hydrographic conditions of the Sea of Japan, but to supplement this data we carried out several surveys simultaneously with the aid of prefectural research boats in May, July and August 1949. Using the material collected by these surveys, we are going to outline the hydrographic conditions during the spring and summer seasons.

As it is rather tedious and futile work to relate the details, of each survey, only the isothermal and isohalinic lines at the surface and the 50 meter depth are shown, (Fig. 1, A-B), considering that it is easiest to tell the warm current water from the cold water by a chart of those depths.

1. *The Warm and Cold Water Masses along Tsushima Current.* It is a well known fact that warm water masses appear on the right side of an oceanic current, and cold masses, on the left side, the former being due to the sinking, and the latter, to the upwelling of the current. This fact was borne out in these surveys.

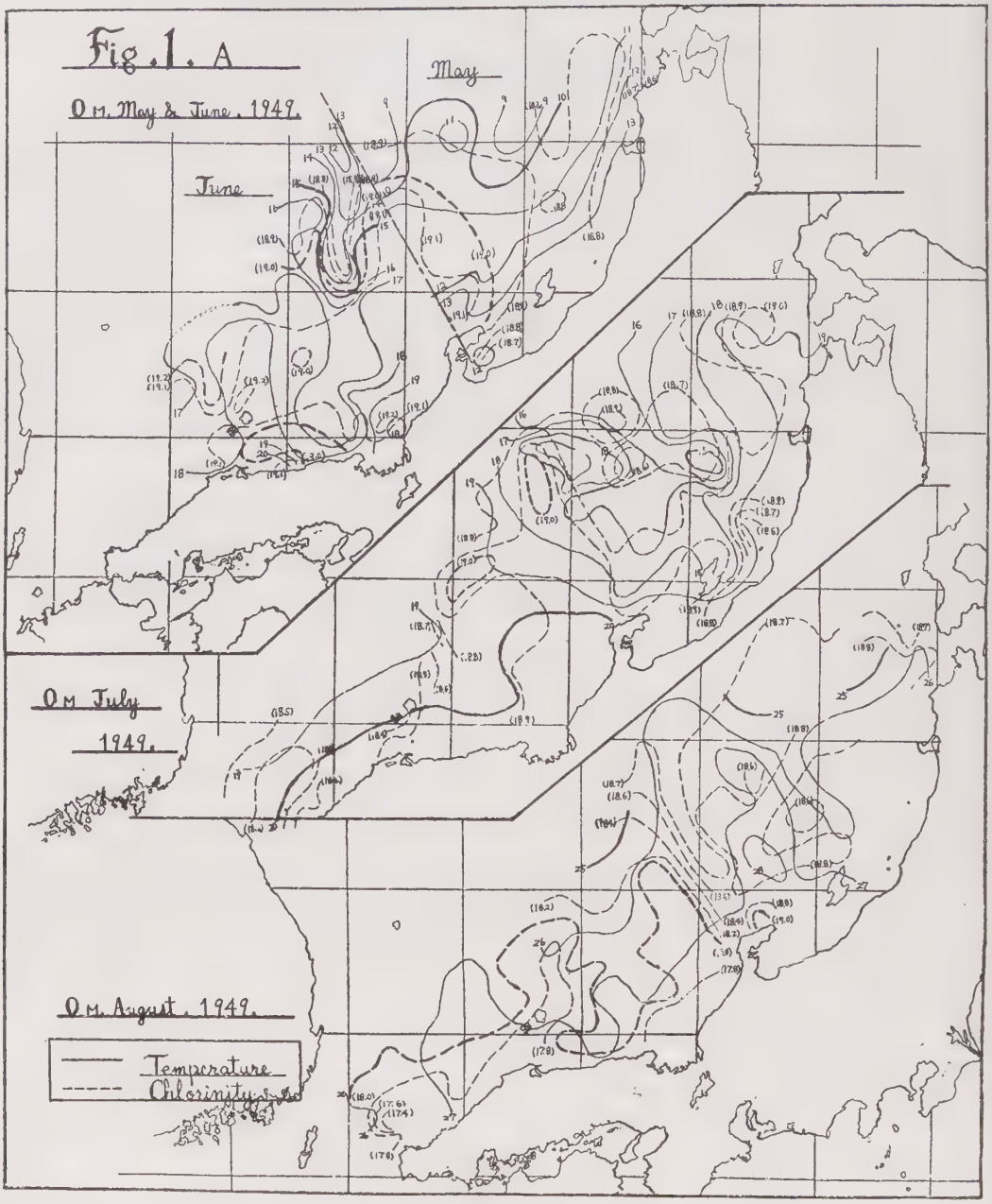
(1) A warm water mass is recognized near Noto-Peninsula; in May, a warm water mass existed due north of Noto-Peninsula and in the coastal district of Echizen. In July, it spreads to the coastal district of the province of Kaga and Echizen, and stays there till August.

(2) In May, an upwelling of cold water was found in the area from Yamato-Bank to the western part of Wakasa Bay. In July it moved west because of the influence of above mentioned warm mass, and in August its position was to the north off of Kyoto Prefecture.

(3) In May, a warm water mass existed along the bathymetric line near Oki Is. In August, it was still recognized off Tajima.

(4) In May, in spite of the fact that observations are lacking near Sado Is. the

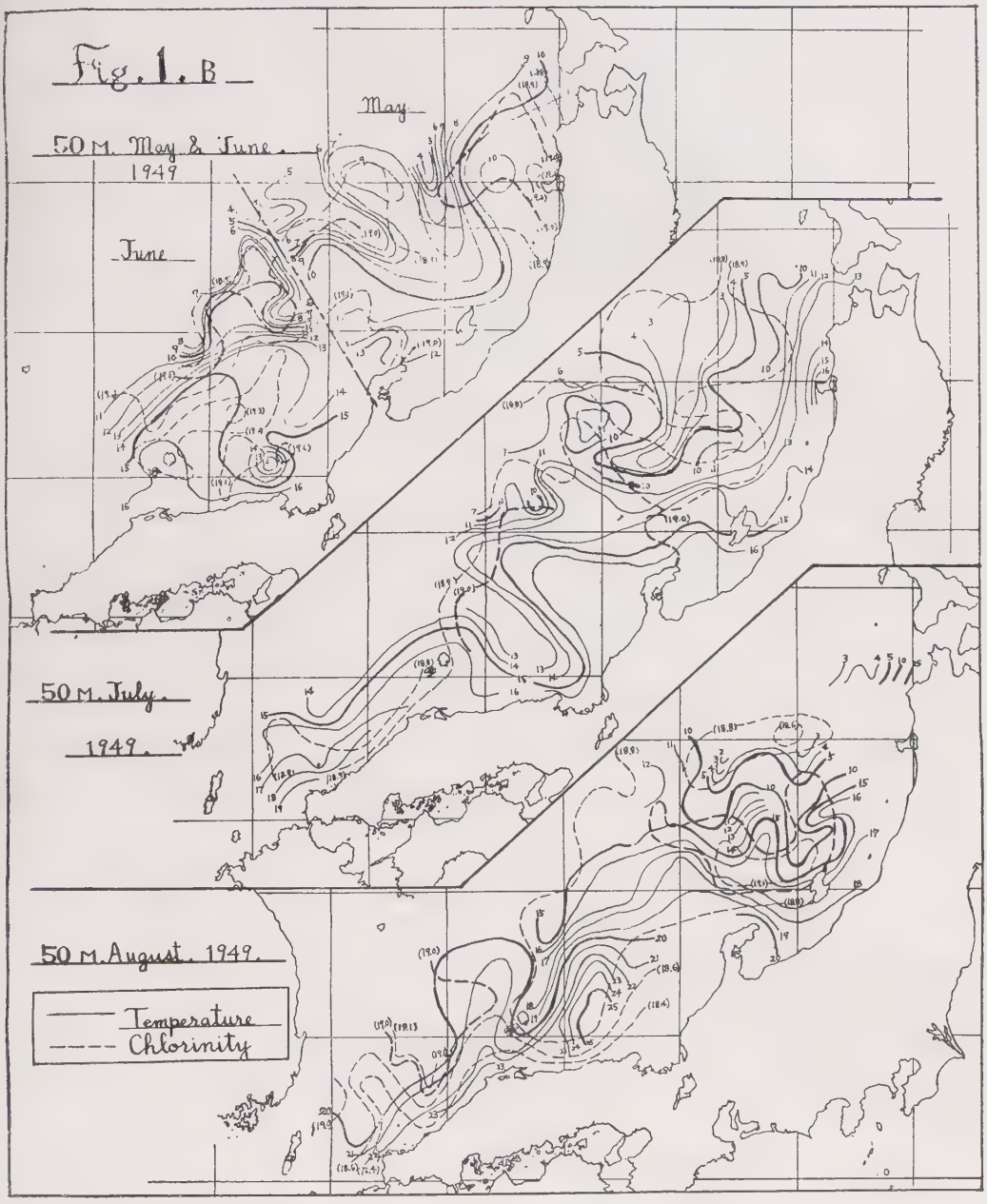
existence of a cold water mass is suggested to the north of that island. It was clearly apparent in July and August, as to the chlorinity, of this water mass was nearly constant from surface to the underlayer.




(5) In May and July, a warm mass was found to the east of Yamato Bank while it was rather obscure in August.

Thus the aspect of serpentiness of the Tsushima Current is rather limited to the east of the Noto Peninsula, while to the west, both warm and cold water masses seem to have a tendency to move westward.

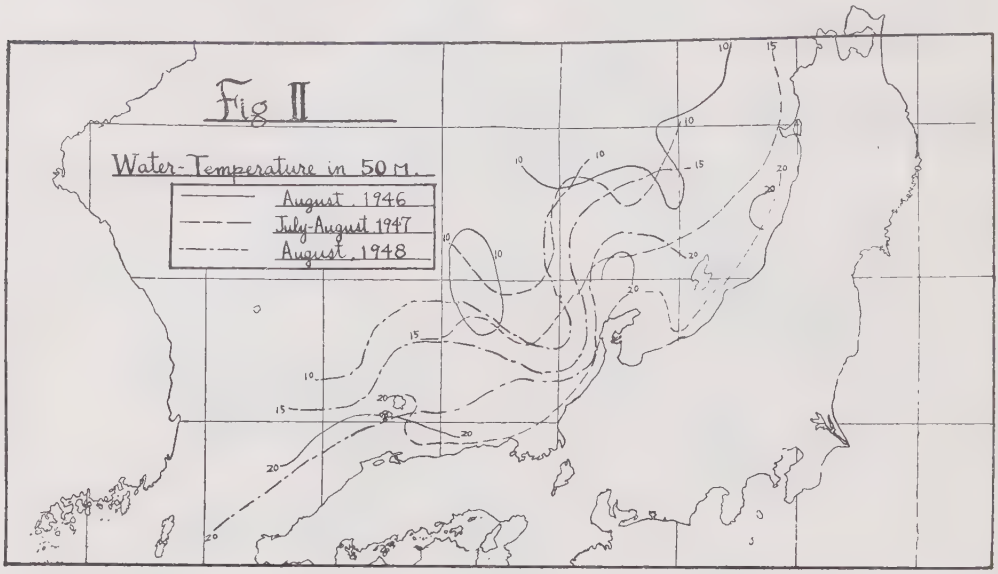
On studying the results of the surveys carried out in summer of 1946, 47 and




48. (Fig. 2) a cold mass was found to the north of Sado Is. Its location was nearly the same as was found in 1951, but in 1949 this mass approached the coast of Sado

remarkably, and it seems to have some relation with the abundant catch of cuttle fish (*Ommastrephes sloani pacificus*) in this area.

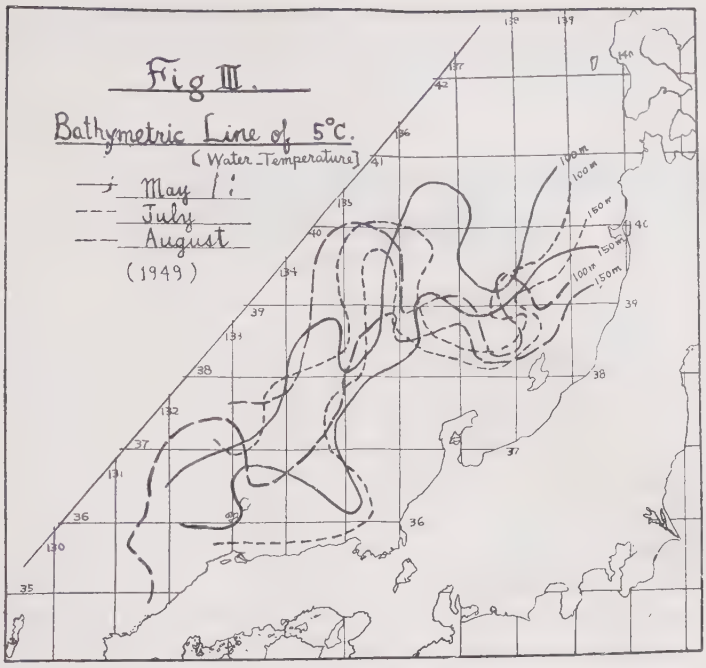
The warm mass due north of Noto seems more variable in 1946 having spread rather widely, in '47 having diminished its area, in '48 shifted its location, and in '49, also having fluctuated.



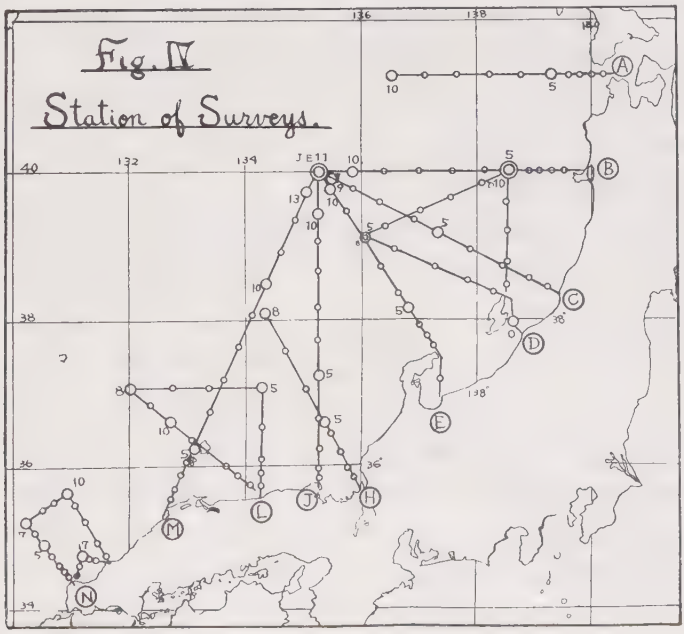

The existence of the cold mass in Wakasa Bay is a well known fact from previous times, and though it was located in nearly the same place during the period 1946–48, it seems to have moved westward slightly.

Thus, along the Tsushima-current, warm and cold water masses appear alternatively, their positions being approximately constant but warm masses seem to be more variable than cold ones.

2. *The Discontinuous Front in the Sea of Japan.* In the layer above the depth of 1500 meters in the Sea of Japan, the water is composed of four main water masses, each of which will be discussed later. These are the surface warm water with high temperature and comparatively low salinity, subsurface warm water with high temperature and high salinity, surface cold water, and so-called "proper cold water in underlayer." The last of them is considered to have its origin in the surface cold which has dived under the warm current. Here we will not describe the surface water because the discontinuous front is not so distinct in that layer. We treat only that between the subsurface warm water and the proper cold water. As the isothermal line is most contiguous in about the 5°C secton of the current, we treat the bathymetric line of 5°C as a sign of this surface. In Fig. 3 it is shown that in

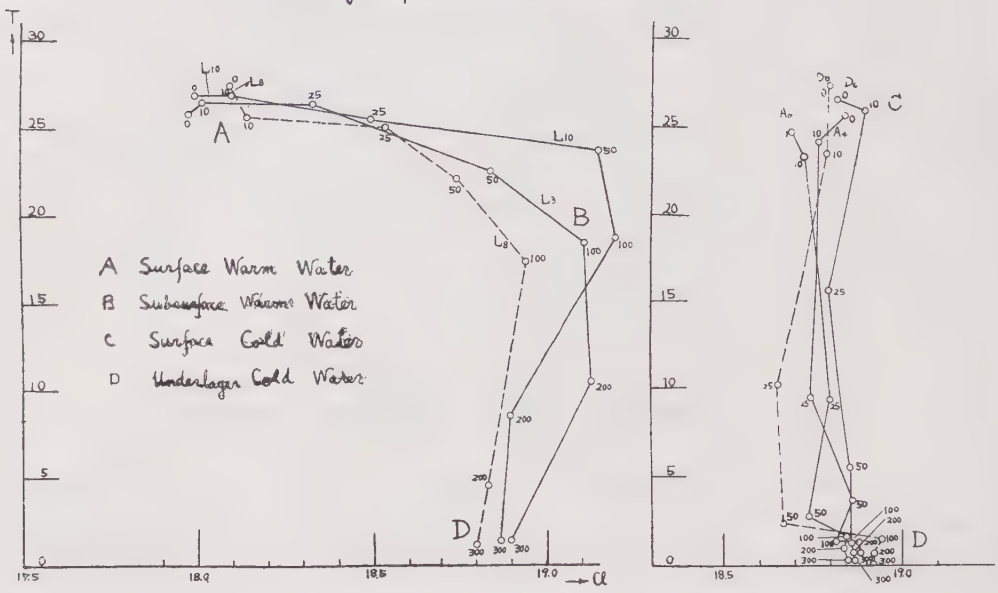



the San-in district this surface approaches closest to the coast in July, and in August departs again slightly, while on the other hand, only little change is shown near Sado Is. It is an interesting fact that the eggs and larvae of Skipper, (*Cololabis saira* (*Brevoot*)) were caught along this frontal line in May.



3. *Four Main Water Masses Composing the Sea of Japan.* In order to describe in detail the character of the above mentioned four main water masses, we shall use the thermo-haline curves (Fig. 5).

Fig. 5. Foundamental Water-mass Composition of Japan Sea (Aug. 1949)




Four types of water-mass are defined by these curves.

(A) *Surface warm water* appears in the surface of the warm current, with high temperature and low chlorinity (18.5 in summer).

(B) *Subsurface warm water* makes up the trunk of Tsushima Current and is highest in chlorinity (19.0–19.2).

(C) *Surface cold water* and

(D) *Cold water in the underlayer* are similar in chlorinity i.e. Cl = 18.8.

The surface water temperature is variable, while that of the (D) layer is nearly constant, i.e. about 2°C.

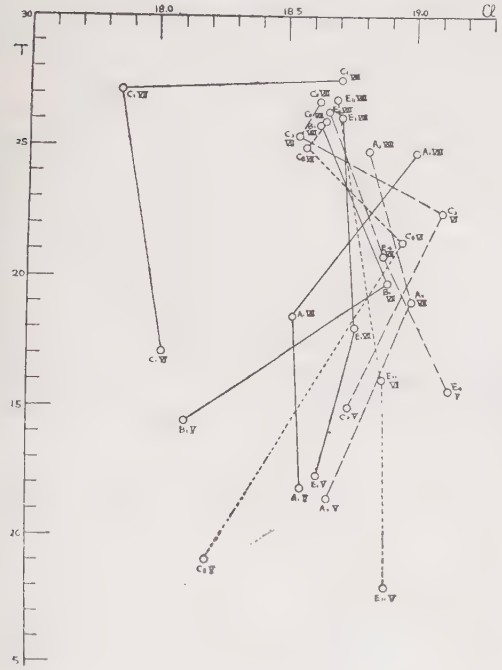
Two types of thermo-haline curves can be recognized, the warm-water type and the cold-water one. The former clearly contain three types of water masses, (A), (B), and (D) and the curve of each station in the warm current shows this type, while the latter lacks (B) and the curve goes from (C) to (D) directly. This second type is seen, for example, in the cold water mass near Yamato Bank. The shape of a curve of the former type convexes to the right (high chlorinity), while in the latter case this cannot be seen. Formerly Dr. M. Uda classified the thermo-haline curves of the

Japan Sea into three types, i. e.: Northern cold water type, southern warm water type, and intermediate type. The last one corresponds to our cold type, but his second type does not appear at this time because our survey did not extend to the northern half of the Siberian side of the Sea of Japan.

4. *Seasonal change of the Surface Water.* It is a well known fact that there is a remarkable distinction in the seasonal change of the surface water between the areas north and west of the Noto Peninsula.

*Northern part.* The surface water of coastal area (St. C-1, A-1, B-1, E-1, D-0, etc. in Fig. 4) is heavily influenced by the inland water. In May, the chlorinity is in general low due to the influence of melting snow, especially or the coast of Uzen from the effect of the River Mogami. In July the chlorinity becomes higher, but the river water still keeps that in the same district low, and in August diminished rainfall and the increased power of the warm current raise the chloronity, gradually with the single exception of the Toyama Bay area. In the middle of the Tsushima Current, however the chlorinity is highest in July, and it diminishes slightly in August. But at St. E-4 (30 M. off Rokko-Zaki) the chlorinity is highest in May, and diminishes in summer, which seems to suggest that Tsushima Current is most powerful in this area in late spring. Far off where the stations are located in cold water (ST. A-4, C-8, and E-11), no peculiarities are shown which indicate the results of the mixing of the warm and cold water on the surface. Yamato Bank (St. E-11) showed only a little change in chlorinity during spring and summer. It is believed that this is due to the fact that the warm current is powerful in this area in the springtime, while in summer, when the currents power is at its utmost, the influence of low haline water is already felt from the west. (Fig. 6)

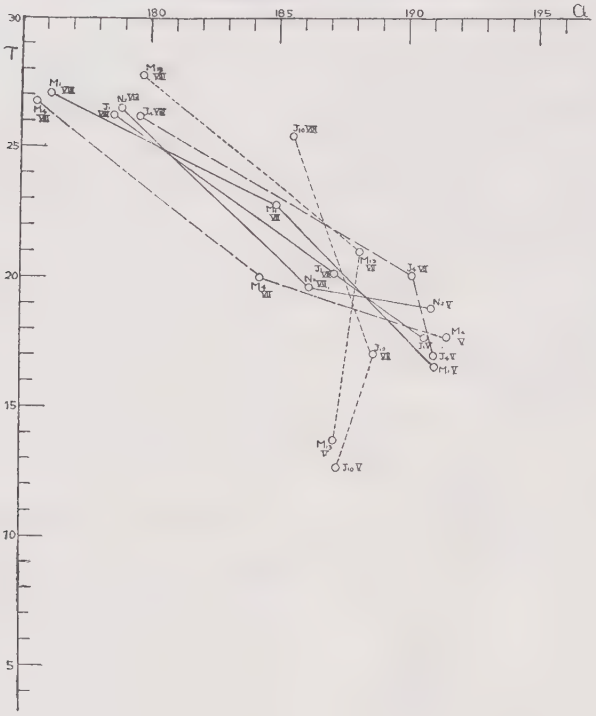
Fig. II a. Seasonal Change of Surface Water. (Northern Part)




Thus, in springtime the Tsushima Current is most powerful off the Noto Peninsula, and this district shows the highest chlorinity, while in the Uetsu district chlorinity is low as a result of melting

snow. Then, as the warm current increases its power in the northern area, the chlorinity becomes higher generally except off Noto. In July this influence does not reach the offing of Tsuruga; from the middle of July, a warm and low-haline water begins to spread on the surface, and the surface temperature rises suddenly while the chlorinity decreases; in August the chlorinity is restored generally, and becomes moreover homogeneous. The origin of the above mentioned warm and low-haline water might be considered to be the coastal water influenced by a large river, for example the Hwang-Ho, but in this case the surface chlorinity of the western area should have suddenly fallen in July. However, this fact is not recognized, and as the chlorinity off Noto is rather

Fig. VI. b. Seasonal Change of Surface Water.
(Western Part.)



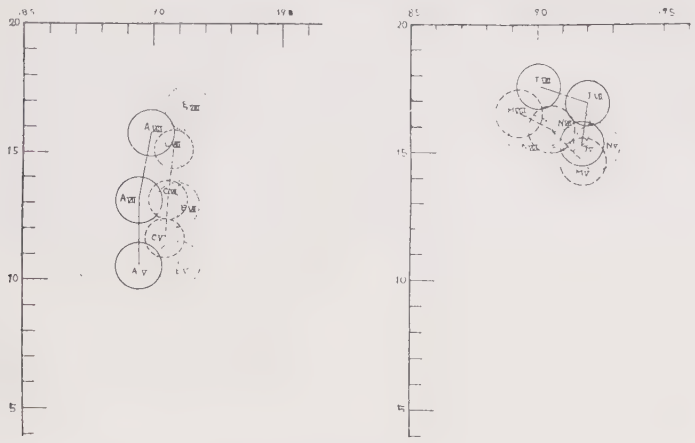

high and is nearly constant during May and July, this hypothesis is doubtful. So we suggest that the surface cold water in the northern area has spread in a film and has been warmed by the solar radiation.

*Western part.* In the coastal area (St. J-1, J-2, L-1, L-2, M-1, M-2, N-1, N-2.), a remarkable rise in temperature and drop in chlorinity is shown. There are significant facts usually observed in the Sea of Japan, and are caused by the effects of the insolution on the sea and rainfall in the continental district. In the middle of the warm current two shaper of change are seen: In Wakasa Bay and the adjacent area

of Noto Peninsula, the change is similar to that mentioned above while the origin of the low-haline water off Ugo is considered different from that off the San-in district.

Thus, there is a distinct front in June between the warm water in the coastal and middle distant area, and the cold water well to seaward; in July, the chlorinity decreases gradually with the rise in the temperature, but this effect does not reach to the offing east of Tajima: in August, this low-haline water spreads widely, so the chlorinity decreases further, and the thickness of the layer of this surface water is about 50–60 meters.

Fig. VII. Seasonal Change of Subsurface Warm Water



(5) *Seasonal change of the subsurface warm water.* The most saline depth was decided by T-Cl curves, and the value of the center, where the points are most contiguous, was adopted as the representative value of the warm water. The same method was used to discuss the seasonal change of the subsurface water. (Fig. 7)

In this case, also a remarkable difference is shown between the northern and western areas. In the former, notwithstanding the rise of temperature, the salinity remained constant, while though the temperature west of Noto remained constant, the salinity decreased remarkably.

Therefore, the effect of the low-haline water riding on the Tsushima Current does not reach the northern area in summer.

6. *Seasonal change of the proper cold water.* The temperature and the salinity of this water is nearly constant, namely, $1^\circ \sim 2^\circ$ C, and Cl = 18.8. The depth of appearance is about 200 meters in the warm current, and less than 50 meters

down the cold water, of the offing. In addition, the proper cold water approaches to the coast in summer.

7. *Note.*

(1) Along the Tsushima Current, warm and cold water masses appear alternatively their positions being stable with slight variations.

(2) The discontinuity between the so-called "proper cold water" and the warm current water shows seasonal variation, and it approaches the coast in July, especially at San-in district.

(3) There exist four main water-mass constructions in the Sea of Japan, namely (a) surface warm water, (b) subsurface warm water, (c) surface cold water and (d) proper cold water in the underlayer.

(4) Comparing the seasonal change of surface and subsurface water in the eastern part of the Sea of Japan with that in the westernpart, a remarkable difference is recognized, while in the proper cold water only a slight change is found.

*Acknowledgement*; We wish to express sincere thanks to Dr. M. Tauchi and Dr. K. Kimura for the enforcement of the surveys and the arrangement of this report.

# PRELIMINARY REPORT OF THE OBSERVATION OF OCEAN WAVES AT HACHIJO ISLAND

K. YOSHIDA, K. KAJIURA and K. HIDAKA

Geophysical Institute, Tokyo University, Tokyo

1. *Introduction* The main purpose of the present investigation is to supply basic data for wave forecasting along each part of Hachijo Island under various meteorological conditions. Since the theories are incomplete at present owing to the complicated characters of ocean waves, it is necessary to make field observations. Present studies are chiefly concerned with results of observations made early in August, 1951, and early in October, 1952, at various points on the island. In conjunction with these observations, wave refraction diagrams were constructed as an aid in interpreting the effects of bottom topography on waves approaching from various directions. Preliminary measurements of wind velocities were also attempted at different elevations above the sea to determine wind stresses acting upon the sea surface.

2. *General conditions of waves* As the water is fairly deep near the coast

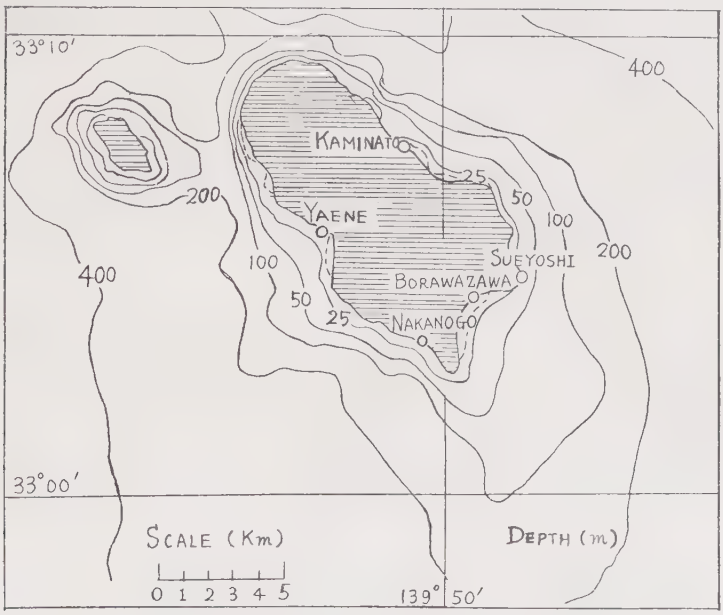



Fig. 1. Bottom topography around Hachijo Island.

of this island, and most of the shoreline is composed of rock walls, waves advance nearly to the beach before losing their essential character and throw up spray upon striking the walls. Consequently, breakers rarely form before swells reach a beach except in stormy weather when waves may reach 5 to 10 meters in height. It has been reported that S to SW winds predominate in this area, and these may be expected to generate very high waves. The bottom topography around this island is shown in Fig. 1, from which it is easily seen that the depth contour of 25 meters is very close to shores,

3. *Observation of waves* Wave recording instruments used in the present studies are of the pressure type, in which the pressure change of air due to wave motion in a pipe fixed in the water is recorded on a chart of a statoscope via a rubber tube. The recorder was successively operated with a chart speed of 33 cm/hour at Kaminato on Aug. 3 and 4 and at Yaene on Aug. 5, 1951. In October, 1952, two wave recorders of the Central Meteorological Observatory located at Yaene were available. One was operated continuously with a chart speed of 33 cm/hour and the other at 12 cm/minute for about 10 minutes at regular intervals from Oct. 6 to Oct. 11. In addition to the recorder, visual observations were made at various localities along the coast.

4. *Wave characteristics* The average period and height of significant waves determined from the records were about 8.5 sec and 1 meter respectively on Aug. 3 and 4, 1951, and about 9 sec and 1 meter in Oct. 6, 7 and 8, 1952. In general waves with a period of 8 to 11 sec seem to prevail in summer and autumn under ordinary meteorological conditions.

The wave recorder in present use has an advantage over the bottom-pressure fluctuation type of recorder for the detailed investigation of actual sea surface wave patterns. One of the records is presented in Fig. 2, and shows that the wave pat-

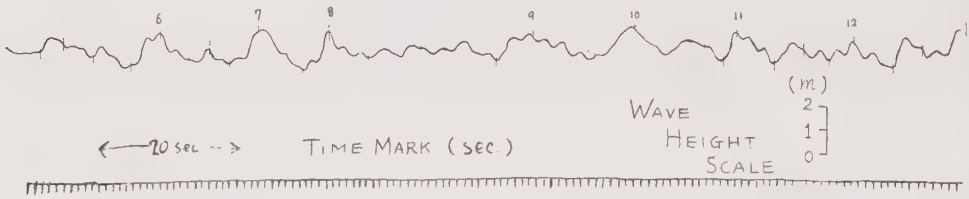



Fig. 2. Record of C. M. O. wave ecorder operated at Yaene on Aug. 7, 1952.

terns are very complicated. Short-period waves of about 2 sec which may be generated by local winds, are superimposed upon the interference pattern of long-period swells of about 8 to 9 sec. Apart from the detailed studies, records run at slow speed are

sufficient to permit research on sea surface waves in which t he effects of very short period waves are eliminated. Some records show that ocean waves include long period components of about 1 to 3 minutes which may be generated near shore or in the open ocean. An example of these records, shown in Fig. 3, was recorded at Kaminato during approximately 2 hours beginning at 1440 on Oct. 3, 1951, under ordinary weather conditions.

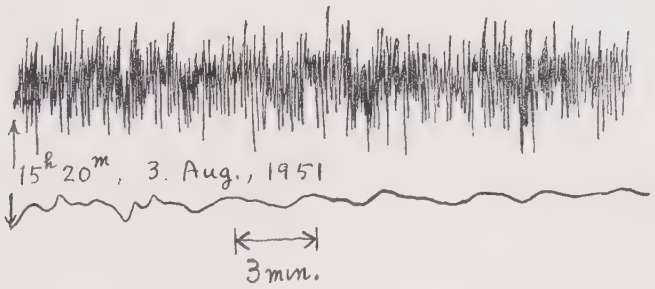



Fig. 3. Upper; A record of wave recorder operated at Kaminato on Aug. 3, 1951, including a long period component of waves. Lower; A long period component obtained by the middle point method.

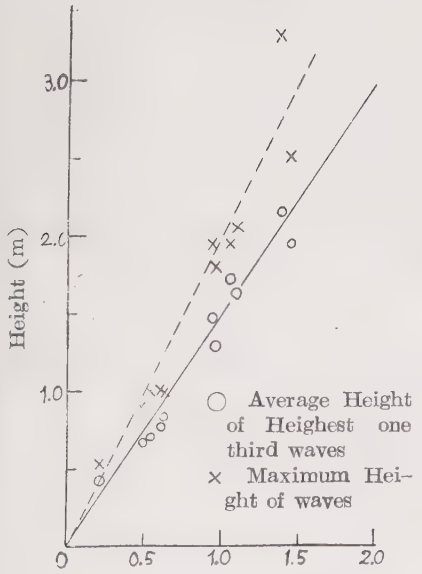



Fig. 4. Relationship between average wave heights, average heights of highest one third waves and maximum wave heights.

Visual observations may also be useful to find the qualitative characteristics of swells when special attention is paid in observing the waves and in interpreting the data. Such data obtained at various localities in October 1952, show a significant relationship between the statistical quantities of waves. The averages of the highest one third waves heights are about 1.5 times the averages of all wave heights, and the maximum wave heights are about 2 times the averages of all. In this relationship the very short waves of irregular appearance are excluded. Periods of waves determined by measuring the time interval from crest to crest vary considerably owing to the interference of waves, but the statistical distribution of periods is close to the frequency distribution of the Gaussian type. These regularities in period and height are illustrated in Fig. 4 and Fig. 5, and are nearly consistent

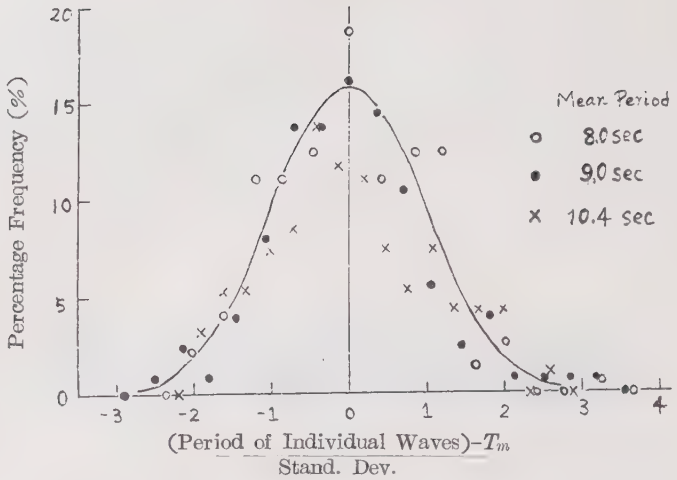



Fig. 5. Ferquency distribution of wave periods.

with the results obtained by H. R. Seiwell[1] and R. R. Putz[2].

The result of a simultaneous observation of waves made at two localities, 40 meters apart, is shown in Fig, 6, and indicates that individual waves change their heights considerably during their advance owing to the interference factor but that the averages over a few minutes are nearly coincident. These composite wave patterns may be similar to those discussed by G. Neumann[3].

5. *The effect of wave refraction* Although an analysis of wave-refraction is very important in order to determine which part of a shore will suffer most from wave attack, owing to the lack of detailed knowledge of the bottom topography only the general features of wave refraction are estimated. Due to the steep slope of the bottom the average swells observed around this island, with periods which range from 8 to 11 sec, are hardly modified until they reach a region are only several hundred meters from shore, so that the remarkable concentration of wave energy does not occur anywhere. According to the observations, however, the actual heights of the waves in a sheltered zone weve always greater than those expected from the refraction diagrams. This fact may be attributed to the variability in the direction of wave travel (R. S. Arthur, 1949) and may be important in wave forecasting. The results of observations made at various part of the island are presented in Table 1.

6. *Growth of Waves* An example of growth of waves, observed on Oct. 11, 1952, is shown in Fig. 7. The wind increased its velocity from 6 m/sec up to 15 m/sec in the morning and remained almost constant during the day. Early in the morning, small waves of about 0.5 m in height and 5 sec in period were observed

and these small waves grew to be about 2 m in height and 8 sec in period about 10 hours later. The forecast of waves made on the basis of the theory of Sverdrup and Munk could not explain the actual characteristics of the waves.

Table 1. Observed Wave Height and the Refraction Factor

| Time and Date Oct. 1952 | Locality | Average of Observed Wave Heights (cm) | Computed Refraction Factor | Note |
|---|---|---|---|---|
| $9^h30^m$, 8th | Sueyoshi | 140 | 1 | Swells from an easterly direction with period of about 9 sec |
| $11^h00^m$, 8th | Borawazawa | 100 | 1/3 | |
| $14^h50^m$, 8th | Nakanogo | 100 | <1/10 | |
| $18^h30^m$, 8th | Yaene | 100 | negligibly small | |
| $17^h30^m$, 6th | Kaminato | 200 | 1 | Swells from a north-easterly direction with period of about 13 sec |
| $16^h30^m$, 6th | Yaene | 30 | negligibly small | |

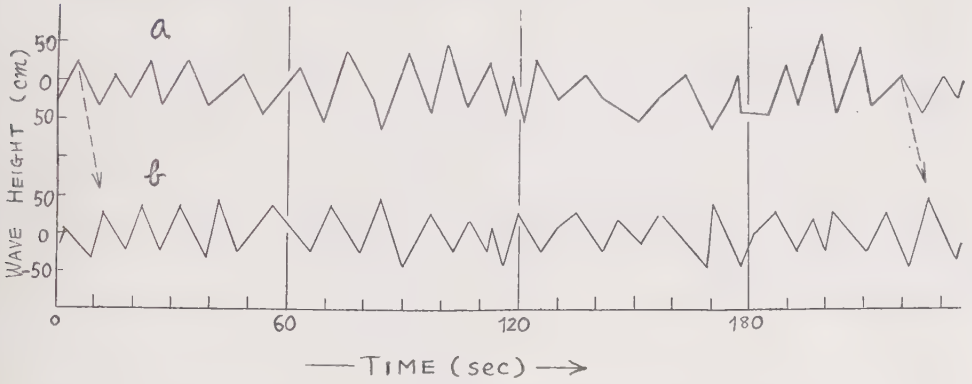



Fig. 6. Wave patterns at two different localities, observed at Yaene on Oct. 11, 1952. b is 40 m downwind from a.

7. *Wind structure near the sea surface* To obtain knowledge of wind stress acting upon the sea surface, wind velocities at five levels between 1 and 11 meters above the sea surface were measured with 5 small anemometers of the Robinson's type on Aug. 4 and 5, 1951 at a location about 1 Km north-west to Yaene. A pole on which anemometers were fixed was set at the head of a narrow long rock juting out into the sea. One of the results, presented in Fig. 8, shows a kink at the height of about 2 m in the profil of the velocity distribution with height. The lower part of this profile may be due to the effects of the roughness of the rock but the upper part seems to represent a true distributions of wind velocity upon the sea surface. The roughness length $z_0$ estimated from the lower part of the profile is about 20 cm, which may be reasonable on the irregular rock surface, and the one

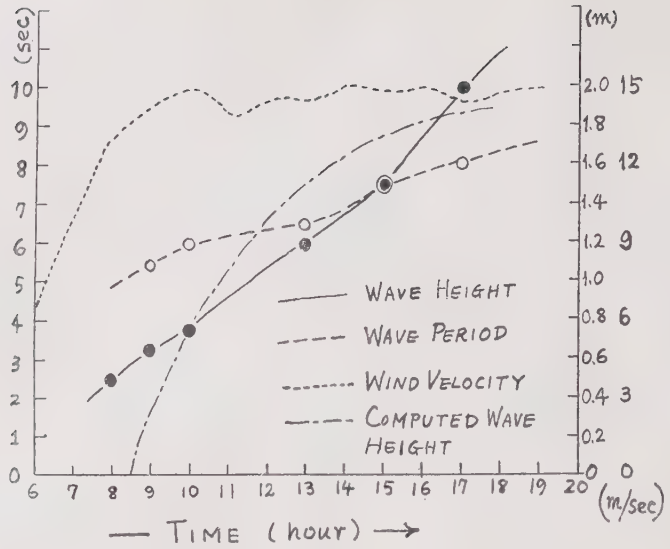



Fig. 7. Wind and wave conditeons observed at Yaene on Oct. 11, 1952. (computed wave heights are based on the duration graph in the case of wind velocity of 10 m/sec)

estimated from the upper part is about 0.05 cm. The fact that the nearly same values for the roughness length are obtained in each observation, (wind velocities were always below 6 m/sec), indicates that the sea surface is smooth and a laminar boundary layer exists next to the sea surface. The studies on wind stresses on the sea surface are very important but no definite conclusions have been obtained as yet owing to the difficulties in observing sea surface wind velocities.

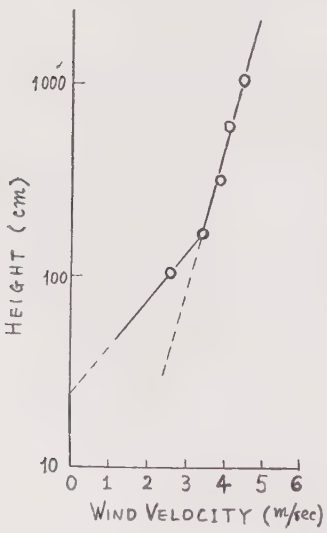



Fig. 8. Velocity distribution of wind with height, measured on Aug. 4, 1951, at Yaene.

8. *Conclusion* In the present report are discussed only briefly the character of sea surface wave patterns, the effect of refraction in relation to the forecasting of waves and the stress of wind on the sea surface. The problems will be more fully discussed in the future.

9. *Acknowledgements* The measurements of the vertical distribution of wind velocities were carried out by Messrs Y. Ogura, Y. Nakagawa and E. Ozawa of the Meteorological Division of the Geophysical Institute, Tokyo University. We are grate fully indebted to Mr. S. Unoki for his assistance in field observations. Dr. M. Nakano of the Central Meteorological Observatory was kind enough to give us a per-

mission to use the wave recorders set at Yaene. The assistance of members of the Meteorological Station of Hachijo Island in field observations and in providing us with the wind data is gratefully acknowledged.

The present investigation has been made as a part of the general researches on Hachijo Island.

*References*

[1] Seiwell, H. R., Results of research on surface waves of the Western North Atlantic. Papers in Phys. Oceanogr. and Meteorol. Vol. **10**, No. 4, 1948.

[2] Putz, R. R., Statistical distribution for ocean waves. Trans. Amer. Geophys. Union. Vol. **33**, No. 5, 1952.

[3] Neumann, G., On wind generated ocean waves with special reference to the problem of wave forecasting. Office of Naval Research Contract No. Nonr-285(05) Department of Meteorology, College of Engineering, New York University. (1952)

[4] Arthur, R. S., Variability in direction of wave travel. N. Y. Acad. Sci., Vol. **51**, pp. 545–569, 1949.

# STUDIES ON MINUTE ELEMENTS IN SEA-WATER

M. ISHIBASHI

Chemistry Institute, Facutly of Science, University of Kyoto

Concerning the elements occurring in sea water, the reciprocal proportion between the major or principal elements dissolved in sea water is quite invariable in the oceans and in the seas, with the exception of a few seas diluted with land water. The amount of principal elements in any sea water, therefore, is not variable in the percentage composition, and varies only in the total salt concentration. The minor or trace elements, however, are not always found in constant relative amounts, varying especially with the concentration of biological activity and with the effect of land water. Data on trace elements by various workers frequently differ from one another, and some of the results seem to be inadequate. Moreover, some elements have not been discovered because of the difficulties of detection. According to present knowledge, more than fifty elements have been detected in sea water or in marine organisms, but probably all the elements occuring in the earth's crust are present also in sea water.

The author and co-workers have carried on "The Chemical Studies on the Ocean"[1] since 1935. During the time, the authors have studied the following divisions: chemistry of sea water, of brine and bittern, of sea lives, and of sea muds.

As a result of research on trace elements dissolved in sea water, the authors found the regularities in the amounts of the elements dissolved in sea water. Comparing the amount of an element in sea water against its atomic number, the tendency is shown for the amount generally to decreases in proportion to an increase in the atomic number. If we take the log m·mol/L for ordinate and the atomic number for abscissa, the amount of elements belonging to the same group in the periodic system of elements — in the case of halogen, for example, then Cl, Br and I but with the exception of F — diminish in a regular manner with an increase in atomic number. In such instances halogen, alkali, and alkali earth elements are seen in a linear relation-ship.[2] The ratio of the amount of an element in sea water tothat of the element in earth's crust has some regular relationship with the periodic system of elements. Assuming that ionic potential, which is the ratio of ionic charge to ionic radius, present the

characteristics of an element, on the whole, the authors have shown a graphical regularity between the ratio of the amount of an element in sea water to that of the element in the earth's crust, and ionic potential. From the regularity, the authors presumed the amount of some undetermined elements in sea water[3].

During these researches, in studing the methods for determining the minor constituents of sea water, the authors have quantified the amounts of the trace elements in sea water by using the methods described below.

Details of the method for each element and their results will be reported in other papers. In this paper, an outline of the procedure for the determination and some examples of the results obtained for a few elements in sea water off Shirahama, Wakayama Prefecture, Japan, are presented.

*Outline of the methods of analysis*

*Vanadium*: 5～10 L of sea water was taken, acidified with 20 ml of HCl and combined with 20mg of ferric iron as $FeCl_3$ solution. Then the iron was precipitated by adding cupferon solution (5g of cupferon) and the solution allowed to stand for 2～3 days. Then the vanadium in the sea water was nearly completely coprecipitated with iron cupferate. The precipitate was then filtered, ashed in a platinum crucible and fused with small amounts of an alkali carbonates mixture. The fused mass was extracted with hot water. The solution was acidified with $HNO_3$, a drop of bromine water was added and the mixture evaporated to dryness. The residue was taken with water, and the solution transfered to 10 ml measuring flask, after which were added 1 ml of $HNO_3$ (1:1), $H_3PO_4$ (17%) and 0.2M-$Na_2WO_4$ solution respectively. The solution was diluted to 10 ml and the resultant color of the solution was measured photometrically.

The recovery of vanadium, in this procedure, was found to be about 90%.

*Chromium*: 40 L of sea water were taken, 30mg of aluminium as $AlCl_3$ solution was added, and the solution neutralized with $NH_4OH$ (1:5) under constant stirring. The solution was allowed to stand overnight to complete the precipitation. The precipitate was filtered, dried and fused with a small amount of fusing mixture. The fused mass was then extracted with hot water, where the solution contained chromate, permanganate and vanadate. A few drops of ethylalcohol were added to the solution in order to reduce the permanganate, then $H_2SO_4$ was added for neutralization. Vanadium was extracted by chloroform as vanadium oxinate. The water solution was acidified with 1 ml of 0.1n-$H_2SO_4$, and were added 1 ml of 0.2% diphenylcarbazide solution and 1 ml of 0.1% phenol solution, after which the solution was diluted to 25 ml. After 10～20 minutes, the resultant color was measured with a

photometer by using $S_{53}$ filter.

The recovery of chromium in sea water was about 100% in this procedure.

*Cobalt*: 40～60 L of sea water was taken and 200mg of ferric iron as $FeCl_3$ solution added. Then Ferric hydroxide was precipitated with 60ml of $NH_4OH$(1:10), and allowed to stand for 2～3 days. The precipitate was filtered, dissolved in 30 ml of hot HCl (1:1), and 10ml of 10% citrate solution was added and neutralized with $NH_4OH$ to border alkalinity. The cobalt was then extracted 3 times with 5 ml portions of 0.01% dithizone chloroform solution. The chloroform extract was evaporated to dryness, and ashed at a temperature less than 500°C. The residue was taken up with aqua regia and evaporated to near dryness. The residue was dissolved in a little water, 3 ml of 10% thiocyanate solution, 3～4 drops of 20% $SnCl_2$ solution and 15 ml of acetone were added, and the solution diluted to 15 ml. The resultant color intensity was measured.

In this procedure, the recovery of cobalt was found to be about 80%.

*Nickel*: 40～60 L of sea water were taken and Ni was coprecipitated with $Fe(OH)_3$. The precipitate was dissolved in HCl and made an alkaline citrate solution as was done in the case of cobalt. Then nickel was extracted 2 times, each time with 10 ml of 1% dimethyl-glyoxime chloroform solution, and re-extracted with 10 ml of 5n-HCl from a chloroform layer. The hydrochloric acid solution of nickel was treated with excess bromine water, neutralized with $NH_4OH$ to 2～3 drops excess after heating, then 1 ml of 1% dimethyl-glyoxime alcoholic solution was added. The solution was diluted to 25 ml, and the resultant color intensity was measured with a photometer.

The recovery of nickel was about 85% in this procedure.

*Arsenic*: 1～2 L of sea water were taken, 20mg of ferric iron as $FeCl_3$ solution added, then the solution neutralized with $NH_4OH$ and allowed to stand over-night. Nearly all of the arsenic was carried down with the precipitated ferric hydroxide. The precipitate was filtered and dissolved in 30 ml of $H_2SO_4$ (1:9). This solution was transfered to arsenic determination apparatus, and the arsenic quantified by the Gutzeit method.

In this precedure, the arsenic was recovered nearly completely.

*Selenium*: 20 L of sea water were taken, 700mg of ferric iron added, and the solution neutralized with 20 ml of $NH_4OH$ under constant stirring. The solution was allowed to stand for 2～3 days to completely precipitate ferric hydroxide. The precipitate was filtered and dissolved with as small an amount of hot $H_2SO_4$ (1:4) as was possible. Then the solution was neutralized with $NH_4OH$, acidified with 3 ml

of $H_2SO_4$ (1:4), and diluted to about 60 ml. 15 mg of arsenic was added as arseneous acid solution and after the addition of 20 ml of $H_2S$ water the solution was allowed to stand overnight. The $As_2S_3$ precipitate was filtered through a glass filter, dissolved with 20 ml of hot nitric acid, and the solution was evaporated to dryness. The residue was dissolved into 20 ml of 47% HBr solution, and 40 ml of $H_2SO_4$ (1:1) added. Selenium was seperated by distillation using the usual method. One ml of 1% phenol solution was added to the distillate. The amount of selenium was then quantified colorimetrically by the thiourea method.

In this procedure, the recovery of selenium was found to be about 70-80%.

*Molybdenimum*: (1) 1～3 L of sea water were taken and acidified with 2～3 ml of $HNO_3$ (1:5), after which 10 mg of $Fe^{III}$ as $Fe(NO_3)_3$ solution and 50 ml of 1 M-hexamin solution were added. The solution was allowed to stand overnight to settle the precipitate. The precipitate was filtered, and dissolved with as small an amount of hot HCl as possible. The solution was poured into an excess of $NH_4$ OH under constant stirring drop by drop. $Fe(OH)_3$ was filtered off, and the filtrate was neutralized with HCl, then acidified with an excess of 5 ml of HCl (1:1). 5 ml of 20% $NH_4SCN$ solution was added, then 5 ml of 10% $SnCl_2$ solution. The molybdenum thiocyanate complex was extracted with 10 ml of freshly distilled butyl acetate. The amount of Mo was found from the resultant color of the butyl acetate layer.

(2) The precipitated $Fe(OH)_3$ by hexamine was fused with $Na_2CO_3$, and extracted with hot water. The solution was neutralized with $H_2SO_4$, and acidified with 2 ml of n-HCl. After adding 1 ml of 0.2% dithiol-n-NaOH solution, the solution was heated on the boiling water for 10 minutes. The dithiol complex was extracted with 10 ml of butyl acetate. The color intensity was measured photometrically.

*Tungsten*: 60 L of sea water were taken, acidified with 2～3 ml of $HNO_3$, and 200～300 mg of $Fe^{III}$ as $Fe(NO_3)_3$ solution were added. Ferric hydroxide was precipitated with hexamethylene-tetramine in a slightly acidic $HNO_3$ medium. Tungsten and molybdenum in the sea water were carried down with the ferric hydroxide. The precipitate was filtered by filter paper, dried and ashed in a platinum crucible at a temperature lower than 500°C. The residue was fused with a small amount of $Na_2CO_3$, then taken up with hot water. The solution was acidified with $H_2SO_4$ and saturated with $H_2S$ in the presence of tartrate. The precipitated molybdenum sulfide was filtered off. The filtrate was evaporated in a platinum crucible to dryness. If necessary, the solution was filtered on the way to evaporation. An excess of $Na_2CO_3$ was added to the residue and ashed cautiously at a low temperature, then fused to melt. The fused mass was extracted with hot water, and the solution

neutralized with $H_2SO_4$, and diluted to 50 ml. One 25 ml portion of the solution was acidified with 2 ml of n-HCl, 1 ml of 0.2% dithiol-n-NaOH solution was added, and the mixture heated on boiling water for 10 minutes. The resultant greenish blue color was extracted with 10 ml of butyl acetate. The sum of the amount of tungsten and residual molybdenum was found from the color intensity of the butyl acetate layer. The other 25 ml portion of the solution was acidified with 2 ml of n-HCl, in the presence of 1 ml of 50 % tartaric acid. The Modithiol complex was extracted in 10 ml of butyl acetate as in the above.

The amount of residual molybdenum was found from this color intensity. The amount of tungsten was found from the difference of the two measurements.

*The results*

Some results were shown in the table 1.

Table I

| Element | Sample Water | | Chlorinity | Quantity of Element |
|---|---|---|---|---|
| | Locality | Data | | |
| Vanadium | Off-shore Shirahama, Wakayama | (Feb. 21, 1950) | Cl=19.25% | 3.4~4.6 γ/L |
| | Pacific Ocean: 31.0°N, 135°E | (Aug. 21, 1949) | Cl=18.98% | 2.6~3.1 γ/L |
| | Pacific Ocean: 31.5°N, 135°E | (Aug. 21, 1949) | Cl=18.95% | 3.4~3.5 γ/L |
| Chromium | Off-shore Shirahama, Wakayama | (Dec. 25, 1949) | Cl=19.16% | 0.04~0.07γ/L |
| | 〃 〃 〃 | (Feb. 21, 1950) | Cl=19.25% | 0.04~0.05γ/L |
| Cobalt | 〃 〃 〃 | (Oct. 20, 1950) | Cl=18.71% | 0.38~0.67γ/L |
| Nickel | 〃 〃 〃 | (Oct. 20, 1950) | Cl=18.71% | 0.7 ~0.8 γ/L |
| Arsenic | Pacific Ocean: 32.5°N, 135°E | (Aug. 20, 1949) | Cl=19.10% | 3.3 ~4.0 γ/L |
| | Off-shore Shirahama, Wakayama | (Feb. 21, 1950) | Cl=19.25% | 5.0 ~6.6 γ/L |
| | 〃 〃 〃 | (Oct. 17, 1950) | Cl=18.77% | 2.5 ~3.6 γ/L |
| Selenium | 〃 〃 〃 | (Dec. 20, 1951) | Cl=18.96% | 4 ~ 6 γ/L |
| Molybdenum(1) | 〃 〃 〃 | (Aug. 12, 1949) | Cl=18.97% | 10 ~11 γ/L |
| | Off-shore Maiko, Hyogo | (Feb. 28, 1949) | Cl=18.30% | 10 ~11 γ/L |
| | Pacific Ocean: 33.0°N, 135°E | (Aug. 20, 1949) | Cl=19.03% | 10 ~11 γ/L |
| Molybdenum(2) | Off-shore Shirahama, Wakayama | (Jun. 13, 1952) | Cl=18.90% | 9 ~10 γ/L |
| Tungsten | 〃 〃 〃 | (Jun. 13, 1952) | Cl=18.90% | 0.09~0.10γ/L |

## *References*


[1] The title of the papers is listed in Bull. Inst. Chem. Res. Kyoto Univ., the commemoration volume for the silver jubilee. (1952) pp. 118–124

[2] M. Ishibashi and Y. Harada, J. Oceanographical Soc. Japan. **3**, 85 (1943).

[3] M. Ishibashi and T. Shigematsu, Bull. Inst. Chem. Res. Kyoto Univ., **27**, 42 (1951).

# A STUDY ON THE PROPERTY OF THE COASTAL WATERS AROUND HACHIJO ISLAND

Y. MIYAKE, Y. SUGIURA and K. KAMEDA

Meteorological Research Institute, Tokyo

One of the interesting problems in oceanography is to discover how the property of the ocean water is affected by the presence of a small solitary island in the far-off sea, and to what extent the coastal water is changed by land water pouring into the sea from such a small island.

Generally, since the land water contains much more nutrient matter than the off-shore water, it contributes to a degree to the biological productivity around the island. Therefore, a study of this problem will give also a basic knowledge for the coastal fisheries of the island.

Fig. 1. The distribution of iso-bathymetric lines (m).

For such a program, the chemical properties of the coastal surface water around Hachijo Island (33° 05′ N, 139° 48′ E) were studied respectively in July, 1951 and

in December, 1952. A number of samples of land water were also chemically investigated during both observation periods with respect to the nutrient matter they contained.

The main current of the Kuroshio (Japan Current) flows to the north between this island and Mikura-Island and one of its branch currents seems to flow along the island from the north-west to the south-east. The current passing through the narrow strait between Kojima and the main island is extraordinarily strong. As the strait is not only narrow but also shallow, as shown in Fig. 1, the current is much intensified there.

Fig. 2. The distribution of silicate-Si ($\mu g$ at/litre.) in summer. July, 1951.

In summer (from 13 to 28 July, 1951), the surface water temperature varied from 23.7°C to 27.4°C and pH of sea water averaged 8.3. The mean chlorinity was 18.75‰.

The concentrations of most of the nutrients were so low that ammonia-N was less than 3 $\mu g$ atoms per litre, nitrite-N was also less than 0.05 $\mu g$ atoms per litre and phosphate-P could be found only in traces. Only silicate-Si was present in an appreciable amount. The amount was about 10 $\mu g$ atoms per litre in the off-shore water (Fig. 2), but increased as the shore was approached until a quantity of 20 to 70 $\mu g$ atoms per litre was present. Nitrate-N was not determined in this season. In winter (from 6 to 14 Dec., 1952). The water temperature of the surface was about

20°C. The chlorinity averaged 19.02‰, which was comparatively higher than in summer. The amounts of the nutrient salts were also larger.

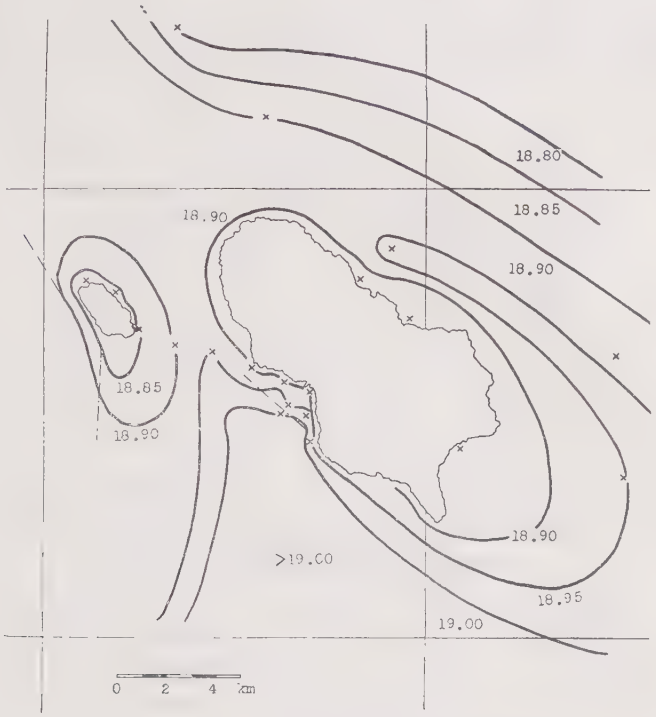



Fig. 3. The distribution of chlorinity (‰) in summer. July, 1951.

Since most of the nutrient matter near the shore is supplied from the land, the chemical analysis of land water is also necessary. There are a number of wells, small springs and a few streamlets in the island. These may be classified into two groups from a chemical point of view. The first group (A) of waters contains much chloride and nutrient matter while the second one (B) contains a considerably lesser amount.

The average concentrations of both groups are shown in Tab. 1.

Table 1

| | | amm. -N μg. at. per litre | nitrite-N μg. at. per litre | nitrate-N μg. at. per litre | phosphate-P μg. at. per litre | silicate-Si μg. at. per litre | chlorinity ‰ |
|---|---|---|---|---|---|---|---|
| Dec. 1952 | A | 3 | 0.10 | 100 | 1.5 | 200 | 0.68 |
| | B | 3 | 0.05 | 12.5 | 0.65 | 175 | 0.04 |
| July, 1951 | A | 4.5 | 0.05 | – | 1.0 | 590 | 1.4 |

It is interesting to note that the content of the silicate-Si in land water was comparatively larger in summer than in winter.

In comparing the land water with regard to the nutrient matter, it is seen that the first group has a remarkably richer silicate and nitrate content than the secord.

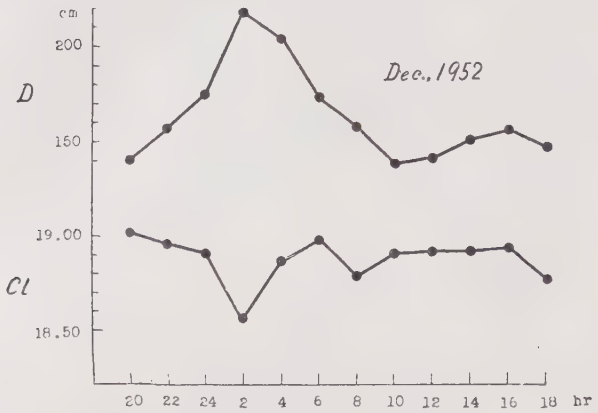



Fig. 4. The relation between the chlorinity and the tide. D; a vertical distance to water surface from a jetty

The daily variations in the concentrations of some chemical substances were observed at a fixed point A (Fig. 1). It was found that the chlorinity change showed a good correlation with the tide, increasing and decreasing in the same direction as the elevation of the water level (Fig. 4 and 5).

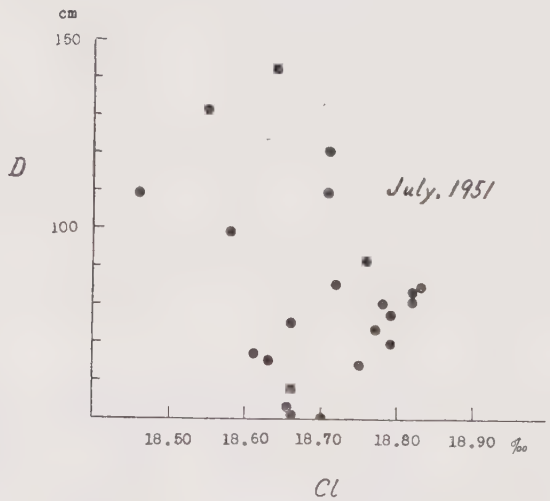
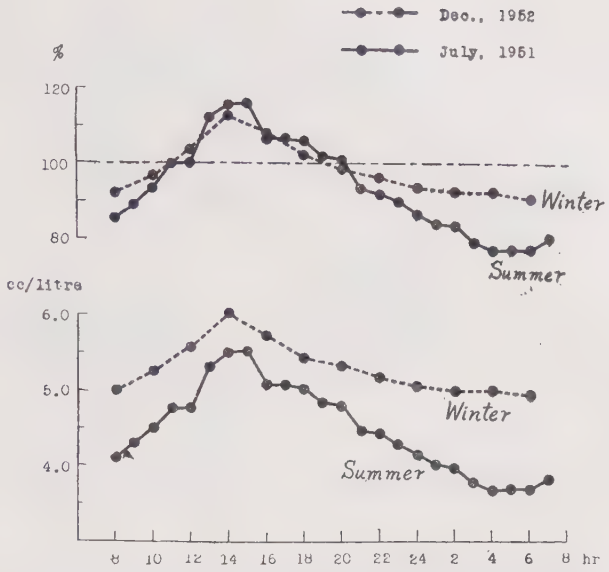



Fig. 5. The relation between the chlorinity and the tide.

The diurnal variation of the dissolved oxygen content is shown in Fig. 6. It is maximum at 14 h and minimum in the early morning. Such a type of variation, resembling that of air temperature, may be regarded as a normal one. In summer

the range of variation is greater than in winter, as the population of living matter is larger in summer.




Eig. 6. The diurnal variation of the dissolved oxygen.

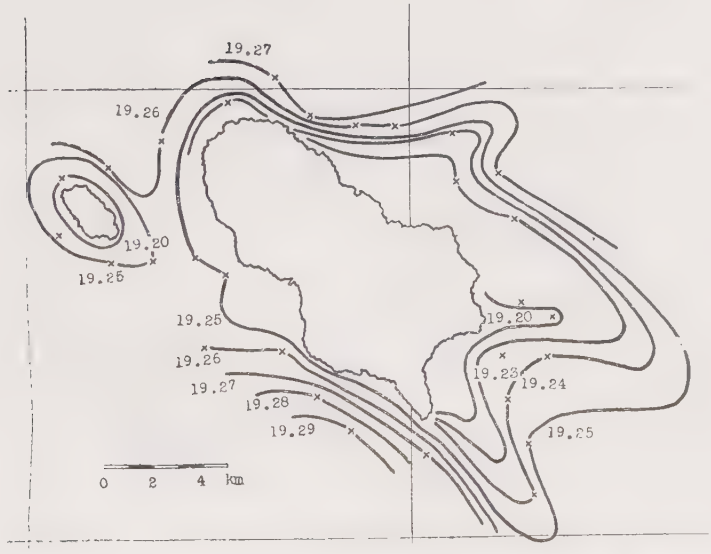



Fig. 7. The distribution of the chlorinity in winter. Dec, 1952.

The effect of the island on the ocean water is shown in Fig. 7 to 10. As seen in these figures the effect is greater in the region from the eastern to the southern

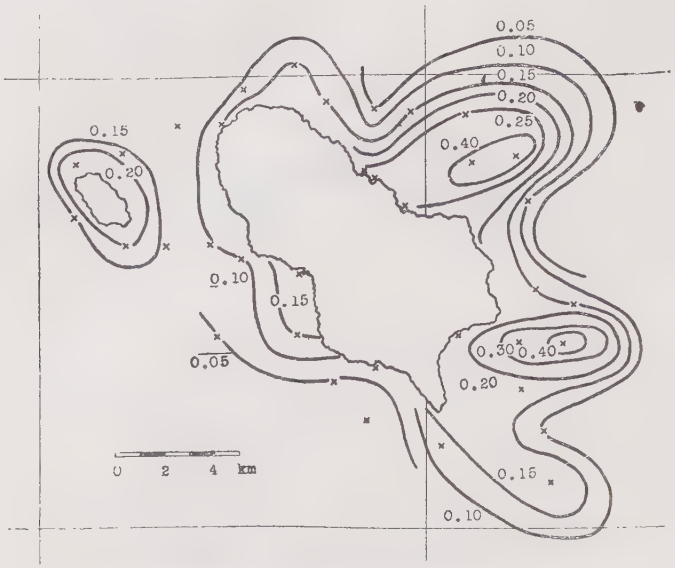



Fig. 8. The distribution of nitrate-N ($\mu g$ at/litre) in winter. Dec., 1952.

coast of the island owing to the different amount of the out flowing land water as well as to the direction of the current. The effect of the ocean current is seen

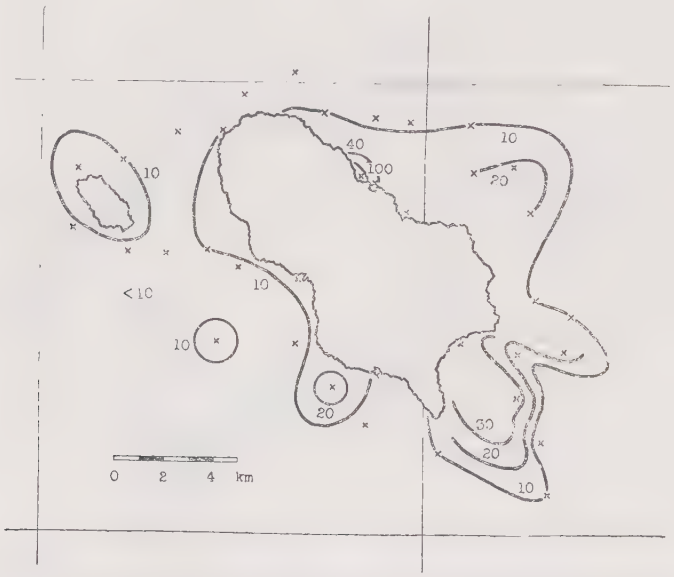



Fig. 9. The distribution of nitrite-N ($\mu g$ at/litre) in winter Dec., 1952.

Fig. 10. The distribution of silicate-Si ($\mu g$ at/litre) in winter. Dec., 1952.

clearly on the southern coast where the shadow of the current is formed. It is to be noted that the fishing grounds around the island agree well with the distribution of the coastal water as shown above.

# NOTES ON THE ECOLOGY OF A PLANKTON COPEPOD, *LABIDOCERA PAVO* GIESBRECHT

S. K. WADA

Oceanographical Laboratory, Meteorological Research Institute, Tokyo.

*Labidocera pavo* was first described by Giesbrecht in 1889. The occurrence in the Red Sea and the Indian Ocean of this animal, although of females only, was reported by Giesbrecht (1891), Cleve (1901, 1903) and Thompson and Scott (1903). Males of this copepod were found for the first time by Sewell (1914) in the Gulf of Mannar, Ceylon. More recently, Mori (1932) found one male in a collection made in the vicinity of the Tokara Islands in the Eastern China Sea, and described the male as new to science. The occurrence of the copepod in the Yellow Sea was also reported by Mori in 1937.

This crustacean has been generally regarded as an oceanic warm water species, occurring rather sparsely; especially, the males have been supposed to be extremely rare. In the summer of 1936, swarms of *L. pavo* were observed at the pier of the Misaki Marine Biological Station, which is situated at the mouth of a small inlet on the eastern coast of Sagami Bay. The waters off the Station are under the alternate or mixed influences of warm oceanic current and neritic water from Tokyo Bay, the oceanic water rather predominating.

Between 1936 and 1952, swarms of the copepod have been observed at a definite season every year; observation was not made in 1945 because of military restrictions. The swarm can easily be recognized by the blue color of the animal. Swarms appear first in the middle of August, and the absence of the animal in the inshore water is generally affirmed for the first time after stormy weather in the middle of October. During this period, the presence of the swarm is always observable; at flood tides, the animals are observed jerking to and fro at the surface of water, sometimes jumping into the air; at ebb tides, the copepods are found swarming near the bottom.

The crustaceans appear in such abundance that they make excellent food for small fishes in the Aquarium of the Biological Station. Hundreds of grams of the copepods can readily be collected by one or two hauls of a small hand net.

Since 1948, daily observations of the water temperature have been made at the pier of the Station. Weekly averages of the temperature during the months from August to October were found to drop from 28° to 20° C. The chlorinity of the water at a station 50 m off the pier during these months, as observed in 1943, gave values of between 17.5‰ and 18.6‰ for the surface, and between 18.2‰ and 18.7‰ for the bottom water (5 m deep).

Swarms of *Labidocera* are found to be composed of adult female and male animals, as well as of various stages of copepodids. Almost all of the adult females are observed to be carrying a spermatophore on the ventral side of their abdominal segments. Adult males can readily be distinguished from the females by various characteristics: smaller size of the body, shape of the abdominal segments, geniculated right first antenna, stoutly modified fifth pair of legs, etc. The body length of the adult female is 2.2–2.3 mm, while that of the adult male is 1.7–1.8 mm (ten measurements each). Sewell (1914) reported that the total length of the adult male was 2.2 mm; the male animal collected by Mori (1932) was about 1.94 mm long.

At night a great many of the animals gather around an electric light. The common copepod animals in the collection, other than *Labidocera*, are usually *Acartia clausi* and a new species of *Tortanus*, both of which are naturally neritic inhabitants.

An aliquot sample of a collection made at night on September 22, 1950 was found to consist of 133 adult females, 304 adult males and 23 juvenile forms. The sex-ratio in adult animals was 1 to 2.3, with the males predominating considerably. All of the juvenile forms were found to be at a rather late stage (Stage V) of copepodid. All of the adult females were also found to be bearing spermatophores. This, of course, indicates the completion of copulation. Eggs which are believed to belong to this species were also found. Nauplius larvae were present in the collection, although, at present, species identification for these forms is difficult. Judging from these facts, it is highly probable that reproduction takes place during the swarming in coastal water.

An aliquot sample of another collection which was made in the daytime on September 1, 1944 was found to contain 119 adult females, 34 adult males and 121 juvenile forms. All of the adult females were carrying spermatophores; the juvenile forms, which constitute 44% of the whole population, consisted of various stages of copepodids, whose body lengths varied from 0.8 mm to 1.7 mm. The sex ratio, female to male, in adult animals was 3.5 to 1.

Judging by the above facts, it is postulated that swarms which are at first com-

posed of adult and copepodid forms develop and breed in inshore waters, dying away after the accomplishment of reproduction. Johnson (1935) reports that *L. jollae* and *L. trispinosa* reproduce during the summer and autumn in southern Californian waters.

At any rate, the two-months' sojourn in the coastal water of swarms of *Labidocera pavo* is one of the most outstanding events on the plankton calender in the neighboring waters of the Misaki Marine Biological Station. According to Dr. Y. Ohshima (verbal communication), swarms of copepods of this species were also observed in shallow waters in June and July of 1938 and 1939 at a point (Ikawazu) of the eastern coast of Atsumi Bay, about 180 nautical miles west from the Misaki Station. In this case, however, the swarm was found to consist of females alone.

In this connection, it should be noted that offshore planktonological observations, which were performed at upper layers in, and in waters adjacent to Sagami Bay, have failed to reveal the presence of any forms of this copepod. (Honjo, 1952; Central Meteorogical Observatory, 1951 a, b, c).

The writer is deeply indebted to the director of the Misaki Marine Biological Station, for the use of laboratory facilities, and to Dr. Jean C. Dan, for her kind guidance in the preparation of the manuscript.

## Summary

*Labidocera pavo* makes its annual appearance in swarms in the coastal water around the Misaki Marine Biological Station. Swarms were observable for two months from the middle of August. Males of this species, which have hereto fore been considered rare, have been commonly found, sometimes exceeding the females in number. The copepods reproduce during their sojourn in the inshore waters.

### *References*

Central Meteorological Observatory of Japan, 1951. The results of marine meteorological and oceanographical observations, No. 3; No. 5; No. 6.

Cleve, P. T. 1901. K. Sv. Vet. Ak. Handl., **35** (5).

—— 1903. Arkiv Zool., **1**; 327.

Giesbrecht, W. 1889. Atti Acad. Lincei. Roma (4) Rend., **5**.

—— 1891. Ibid., **7**.

Honjo, K. 1952. Journ. Oceanogr. Soc. Japan, **7** (3/4): 77.

Johnson, M. W. 1935. Biol. Bull., **68** (3): 397.

Mori, T. 1932. Zool. Magazine (Tokyo), **44** (523): 167.

—— 1937. The pelagic copepoda from the neighbouring waters of Japan. Tokyo.

Sewell, R. B. S. 1914. Spolia Zeylanica, **9** (35): 191.

Thompson J. C., and A. Scott. 1903. Ceylon Pearl Oyster Fisheries and Marine Biology, Pt. 1, Suppl. Rep. No. 7: 227.

# OBSERVATION ON SOME MARINE LUMINOUS ORGANISMS OF HACHIJO ISLAND, JAPAN

Y. HANEDA

Yokosuka Education Board and Jikeikai Medical College.

Hachijo Island, a small volcanic island situated 157 miles south of Tokyo at lat. 33°2′−9′N, and long. 139°43′−50′E, has an area of 69 square kilometers. The average temperature in January and February, the coldest season of the island, is 10°C, and the lowest temperature is over 7°C. In spite of being situated comparatively near to Tokyo, its climate is mild and subtropical. As I visited the island twice, in June, 1951 and September, 1952, to investigate luminous organisms, I wish to describe some interesting problems related to it.

1. *Luminous Ostracoda.* Dr. E. KAJIYAMA (1912-13), has described fortyfive species of Ostracoda in the sea around Misaki, Japan, among them, the two luminous species, *Cypridina hilgendorfii* MÜLLER and *C. noctiluca* KAJIYAMA belonging to the family Cypridinidae. The former is the well known luminous Ostracoda which produces a luminous secretion and can be preserved in a dry condition. It appears commonly along the coast of Honshu, Shikoku and Kyushu, Japan. The latter is a tropical species, very commonly seen in the sea near Palao, Java and Malaya. It is slightly smaller than *C. hilgendorfii*, being 2mm. long and pyramidal in form. It is a pelagic species, and can be taken only by a plankton net, since the animals are not affracted to fish bait. At Hachijo Island, as in the tropical seas, *C. noctiluca* is abundant but no specimens of *C. hilgendorfii* appear.

In a collection made at Aigae Bay, Nakanogo Village, in September, 1952, *C. noctiluca* and a non-luminous species, Cypridina bairdii BRADY, Cypridina (immature) and Codonocera weberi MÜLLER were taken at the same time. Upon separating the species, I was convinced that *C. noctiluca* is the only one which emits light. The color of the light and its secretory behavior are the same as that of *C. hilgendorfii*. When water is dropped on dried *C. notiluca* it emits light. I tested the color of the luminescence resulting when luciferin and luciferase of the two species *C. hilgendorfii* and *C. noctiluca*, and the non-luminous Cypridina are "crossed", as shown in the following table. However the color of the light of *C. hilgendorfii* and of *C. noctiluca* were quite the same, so I could not observe any interesting result on these

two species like that made by concenrning luciferin-luciferase interaction be- tween *C. hilgendorfii*, having a bluish light, and Jamaican Cypridina having a yello- wish light Dr. HARVEY (1924).

| Hot water extract | Cold water extract | Luminescence |
|---|---|---|
| *C. hilgendorfii* | *C. noctiluca* | + |
| *C. noctiluca* | *C. hilgendorfii* | + |
| *C. hilgendorfii* | *Non-luminous Cypridina* | — |
| *C. noctiluca* | *Non-luminous Cypridina* | — |
| *Non-luminous Cypridina* | *C. hilgendorfii* | + |
| *Non-luminous Cypridina* | *C. noctiluca* | + |

When a cold water extract of live *C. noctiluca* is allowed to stand until the luminescence disappears, it would not emit light when ATP (Adenosinetriphosphat) is added.

A report of the results of experiments on ATP reaction and luciferin-luciferase reaction by Dr. HARVEY and myself is now in press.

2. Luminous Fish, *Anomalops katoptron.* In the Banda Sea in Indonesia, two species of well known luminous fishes are found, *Anomalops katoptron* and *Photoblepharon palpebratus.* These two species have a large half-moon shaped luminous organ below the eye.

*Anomalops*, meaning " irregular eye ", is able to shut off the display of luminescence at will, by turning the organ, so that the luminous part is turned out of sight and a black non-luminous part takes its place. An tnteresting feature of these fishes is that the luminous organs are removed and used by the Banda peoples as a bait for fishing. *Anomalops* is found in the sea around Banda where it is very common, but it also occurs less commonly in the sea of Ambon, Menado, Fiji, New Hebrides, Paumotus and Raratonga. In June, 1942, I had the opportunity to visit Ambon and West New Guinea and saw shoals of *Anomalops* at the surface of the water in the harbour of Manukuwari on the north-west coast of New Guinea. At that time I could collect three small specimens, and was able to observe their luminescence. When this fish is swimming under natural conditions, the luminous surface appears and disappears intermittently, and a shoal of the fish seen in the dark swimming at the surface of the sea is a very beautiful sight. If a specimen is caught and put into a glass jar, its luminous disply becomes irregular if the water is in any way unsuitable. A specimen in an aquarium kept in a dark place which is suddenly illuminated by switching on an electric light will cease to display luminosity of either one or both organs. In daylight the fish will not display its luminosity, but if the

place in which it is kept is suddenly darkened, its luminosity is immediately displayed and appears as a bluish-green light.

It was a very remarkable case that in 1942 *Anomalops* was recorded in Japan by Dr. ABE. It was caught in the sea near Kominato, Chiba-Pref., Japan, by a fisherman. It is very interesting that at Hachijo Island, also, three specimens have been collected. The first specimen was reported by Dr. ABE (1951). According to him, on December 16, 1914, Mr. Kitaro OZAWA presented to Mitsune Primary School a fresh specimen which was taken by himself with hook and line near Kominato Bay at a depth of some 300 meters. The specimen is 200 mm. in total length. The second and third specimens were found by myself among some preserved fish materials at the Hachijo Branch of Tokyo-to Fisheries Experimental Station. Though the date of collection of these two specimens is not recorded, it has been said variously that these were taken some seventeen or eighteen years ago by hook and line, and that the fish, which had been killed by a sudden low temperature of the sea in winter, were cast by waves on to the beach. It seems that of though these two specimens were preserved in formalin in a fresh condition, the luminous organ of one specimen has putrefied, while that of the other is in a perfect condition. The former specimen is 190 mm. in total length; the diameter of the eye is 20 mm. and the cavity of the luminous organ is 24 mm. in length. The latter specimen is 145 mm. in total length; the diameter of the eye is 14 mm. and the cavity of the luminous organ 17 mm. The luminous organ is 14 mm. long. 5.5 mm. wide and 1 mm. in thickness, forming a compact mass of cream-colored tissue, lying in a depression just under the eye. The back of the organ is covered with a black pigmented layer. Althongh luminescence is continuous in the organ, in the sea the light is constantly being turned on and off. In a parallel section of the organ it is easy to see a large number of gland tubes parallel to each other and extending completely across the organ, from the back pigmented surface to front transparent surface, with blood vessels running between them. Dr. HARVEY (1921) has suggested that the luminescence is due to symbiotic luminous bacteria. In his study he stated that he had cultured bacteria from these luminous organs, but that these cultured bacteria were not luminous. In my former report (1942), my culture test from the organs agree with the result to Dr. HARVEY's test, althongh I doubtful of the bacterial origin. I found that the cells of the organ were different from those in the other symbiotic luminous fishes, *Monocentris*, *Physiculus*, *Malacocephalus*, *Acropoma* and *Leiognathus* and that the organ was closed, i.e., it had no duct to the exterior. The material examined at Manukuwari, consisted of only three small specimens. This time upon investigation of the large specimen collected at Hachijo Island, I was able

to find the duct to the exterior in the luminous organ which I overlooked in my former report. The opening to the exterior is considered to be the small depression dorso-anterior to the luminous organ, as shown in Figs. 3 and 4, and also the pores scatterred over the surface of the organ as shown in Fig. 4. It then, the organ is one of the open type, the bacterial origin theory gains the advantage, supported by the fact that the luminescence is continuous. I am intending to study this interesting problem, since there will be an opportunity to collect fresh specimens in the future.

*Acknowledgment*: I wish to express my hearty thanks to Prof. Dr. S. HATAI, Chairman of the Pacific Science Congress in Japan and to Prof. Dr. K. HIDAKA, Chairman of the Committee on Biological and Oceanographical Research of Hachijo Islands, who has given me the opportunity to do this present work. I must also express my sincere gratitude to Dr. E. Newton HARVEY, Professor of Princeton University, who given me instructive advice in many ways, and also to Dr. W. L. TRESSLER, the United States National Museum in Washington who identified Ostracoda.

The materials were stained by 500,000×alminium morin, and observed by Dr. YASAKI's ultra violet ray fluorescence microscope.

*References*

[1] ABE, T. 1942, Annot. Zool Jap. 21 [1] 55–57., 1951 Jap. Jour. Ichthyology 1: 304–305.
[2] HANEDA, Y. 1943, Kagaku Nanyo 5. [2] 81–88.
[3] HARVEY, E. N. 1921, Science 53:314–315., 1923 Fybl. Carneg. Instn. 312, 43–60. 1924 Amer. J. Physiol. 70:619–623., 1925 Nat. Hist. N. Y. 25: 353–356., 1952. Bioluminescence, Academic Press inc. New York: 299–331, 520–525.
[4] HARVEY, E. N. and HANEDA. Y.. 1952, Arch. Bioc. Biophys. 35: 470–471.
[5] KAJIYAMA, E. 1912–13, Zool. Mag. Tokyo 24 (287): 488–492, 24 (289): 609–619, 25 (291): 1–16.
[6] YASAKI Y. and SHINOTO, Y. 1952. Cytologia 17 (4).

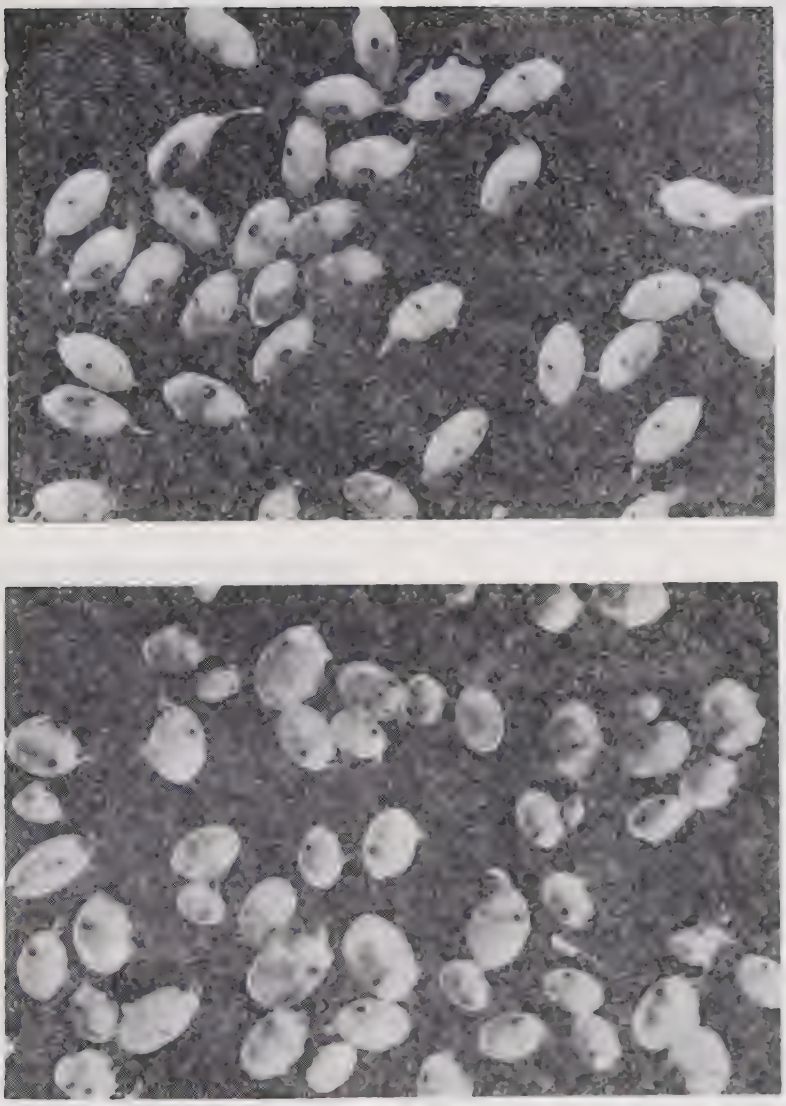


Fig. 1. *Cypridina noctiluca*, a luminous Ostracoda (above) and *Cypridina* sp. (immature), a non-luminous Ostracoda (below), collected near Hachijo Island.

Fig. 2. The second (below) and the third (above) specimens of *Anomalops katoptron* taken near Hachijo Island.

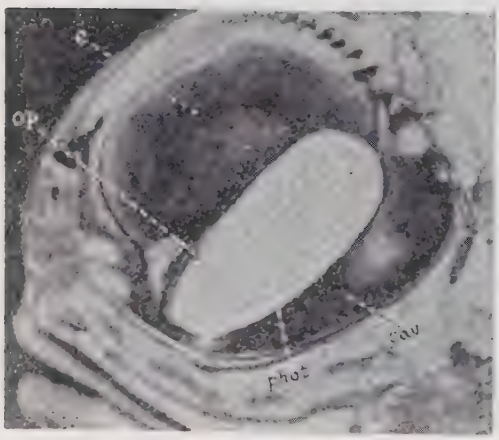



Fig. 3. Luminous Organ of *Anomalops*, showing the opening to the exterior. Phot: luminous organ; op: opening to the exterior; e: eye; cav: cavity of the organ with black pigmented tissue forming a pocket.

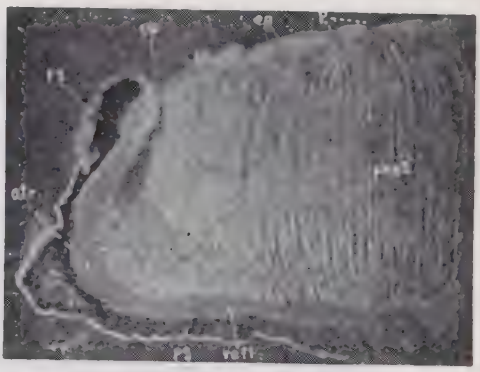


Fig. 4. Parallel section of the organ.

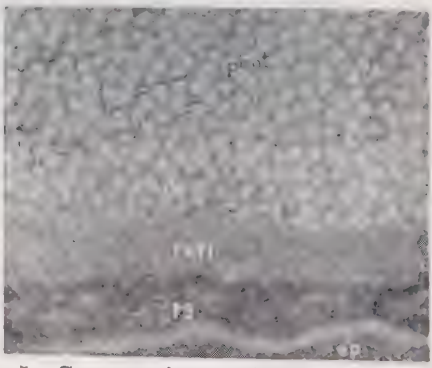


Fig. 5. Cross section of the organ. p: pore passing through epidermis; op: opening to the exterior; ep: epidermis; phot: luminous gland tubes; refl: reflector; pg: black pigmented tissue; atr: blood vessels.

# ON SOME NEW OR NOTEWORTHY ALGAE FROM HACHIJO ISLAND

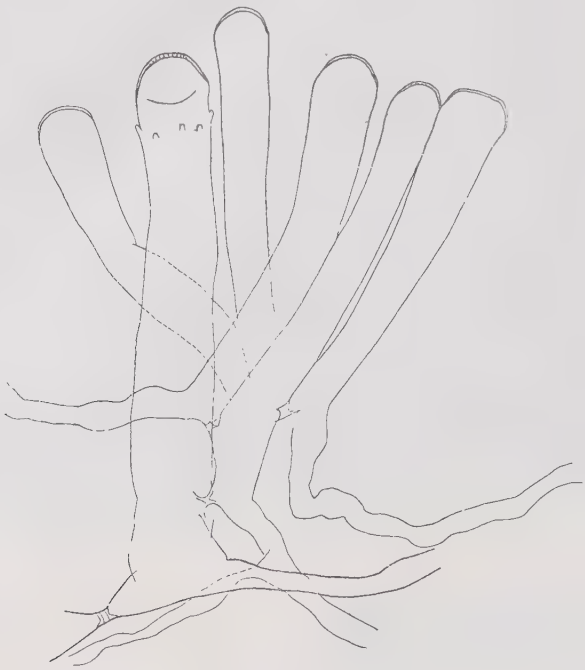
Y. YAMADA and S. SEGAWA.

Hokkaido University, Sapporo and Kyushu University, Fukuoka

1. *Codium Lucasii* SETCHELL. (Text-figs. 1-2.) In the summer of 1951 the present authors found on the vertical face of a rock in a tide pool at Taredo, Hachijo Island, a species of *Codium* which creeps on the substratum and is strongly iridescent. At once it came to the senior author's memory that the same alga had been collected by him at Kashiwajima Kōchi Prefecture, some years ago. It was picked up by a diver from the bottom 2-3 m deep, creeping on a dead coral block. These specimens, both from Hachijo and Kashiwajima, creep on the substratum like *C. adhaerens* AG., but are more black in colour, very strongly iridescent, and not orbicularly spread, but giving off broad lobes which coalesce with those of adjacent thalli to form a close, flat pattern. When the senior author examined his Kashiwajima specimens microscopically in 1941, he thought they might represent a new species and named it *C. kashiwajimanum* YAMADA, but as no gametangia were found that name has not been published. Soon after the discovery of the same species in Hachijo, SILVA's very precise paper on Californian *Codium* was received. Examining it the authors came to the conclusion that the present specimens relate very closely both to *C. Hubbsii* DAWSON and *C. Lucasii* SETCHELL. According to the descriptions, the difference between these two species is to be found in the following points. In *C. Hubbsii* DAWSON, the length of the utricle is 800-1500-2000$\mu$, and the gametangia are cylindrical to slightly fusiform, and 50-100$\mu$ in diameter, while in *C. Lucasii* SETCH., the utricles are 435-600$\mu$ long, and the gametangia are stout and ovate, and 108-123$\mu$ in diameter. In the length of the utricles, the present specimens agree clearly with *C. Lucasii* SETCH., and it seems reasonable to refer the plant to this species, although no gametangia have yet been

Text-fig. 1. *Codium Lucasii* SETCHELL. x 1.

found in the specimens. It must be noted, however, that in no description of *C. Lucasii* SETCH. is there any statement about iridescence, which is very strong and peculiar in the present specimens, as noted above.



Text-fig. 2. *Codium Lucasii* SETCHELL. Utricles. x 70.

2. *Chrysymenia Okamurai* YAMADA *et* SEGAWA sp. nov. (Text-figs. 3) Syn. *Chr. Kaernbachii* OKAMURA (non GRUNOW), Alg. Isl. Hatidyo (Rec. Oceanogr. Works Jap., Vol. 2, no. 2, 1930) p. 96; Id. Icon. Jap. Alg., vol. 6, no. 8 (1932) p. 77, pl. 288, figs. 1–8; Id., Nippon Kaiso-shi (1936) p. 669.

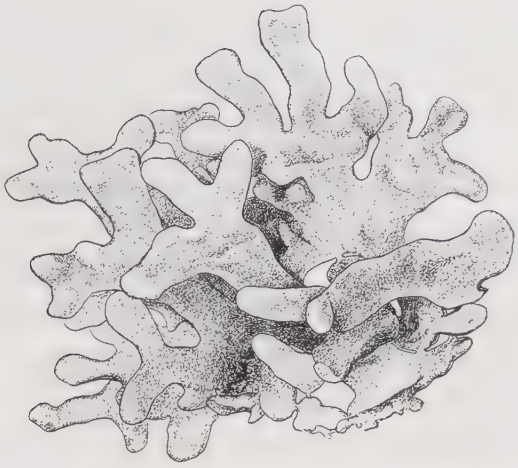
Japanese name: Hanasakura.

Loc.: Sokodo and Borawazawa, Hachijo Isl.

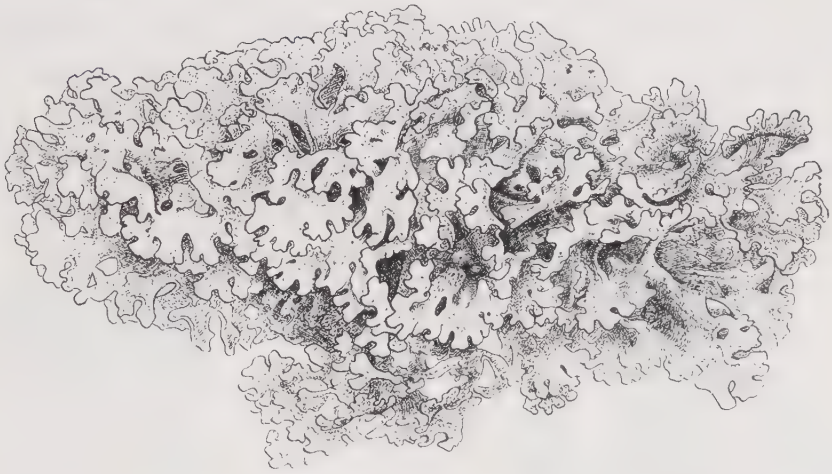
In 1930 OKAMURA reported a new alga under the name of *Chrysymenia Kaernbachii* GRUNOW from Hachijo Island; since then the same alga has been reported from Tosa, and the Kii and Izu Peninsulas. A precise description with accompanying good illustrations is to be found in OKAMURA's Icones of Japanese algae, Vol. VI, no. 8.

In July, 1952 the present authors also collected several specimens of the same alga as above, cast ashore at Sokodo and Borawazawa, Hachijo Island, and had an opportunity to examine the alga in question. When these specimens were collected the senior author could not help harbouring a doubt about the name of this species, because he believed that he had collected a specimen of *Chrysymenia Kaernbachii*

GRUN. at Ponape, Marianna Islands, some years ago, which was quite different from the Hachoji specimens.



Text-fig. 3. *Chrysymenia Okamurai* YAMADA et SEGAWA. x 1.



Text-fig. 4. *Chrysymenia Kaernbachii* GRUN. A specimen from Ponape Isl. x 2/3.

Beside GRUNOW, who named this species, Me-WEBER VAN BOSSE also reported *C. Kaernbachii* GRUN. from the Malay archipelago and gave a description and figures of her specimens. As will be clearly seen the difference between WEBER's specimens and the Hachijo specimens is too wide to consider them as the same species. WEBER noted some differences between her specimens and GRUNOW's, which she examined herself, but referred her specimens to GRUNOW's species. The Ponape specimen at hand coincides fairly well with WEBER's description and figures. Therefore there seems no doubt that the Ponape specimen must be called *Chrysymenia Kaernbachii* GRUN., and consequently the Hachijo specimens must be called otherwise; and here

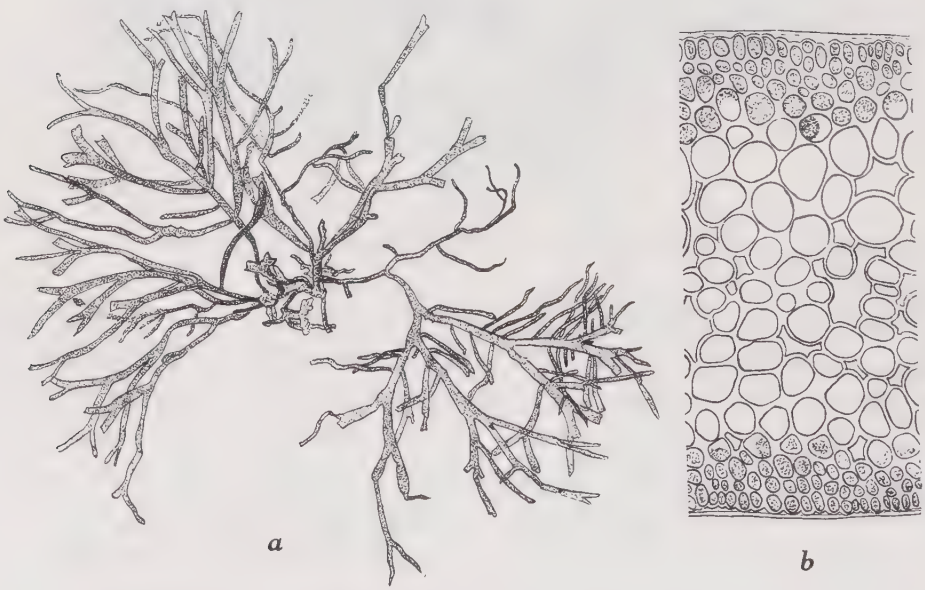
here the authors propose for them a new name, *C. Okamurai*, commemorating their teacher, the late Dr. KINTARO OKAMURA.

3. *Gelidiopsis hachijoensis* YAMADA *et* SEGAWA *sp. n.* (Text-fig. 5) Frons dense caespitosa, late pulvinata, ex parte basale repente et parte erecta composita; parte basale irregulariter ramosa cylindracea, disco parvo irregulariter expanso adfixa, implicata, multa segmenta erecta exsurgente; segmentis erectis 3–7 cm altis (raro 9 cm attingentibus), basi cylindraceis, sursum complanatis, sed interdum partibus superioribus filamentosis arcuatis, saepe implicatis, raro adhaerentibus, repetite (plerumque 4–5-ies) di-vel trichotome ramosis; ramis distichis, nonnunquam ramulis patentibus pinnatis ornatis, sursum attenuatis, ad apicem rotundatis; cellulis medularibus tenuioribus paucis: cystocarpiis, antheridiis et tetrasporangiis ignotis.

Japanese name: Hachijo-Tengusa-modoki.

Loc.: Ōkataura, Hachijo Isl.

Frond densely caespitose, forming an expanded cushion, composed of creeping basal part and erect one; basal portion irregularly branched, cylindrical, attaching to the substratum by means of an irregularly expanded disc, entangled, sending off many erect shoots; erect shoots 3–7 cm high (rarely reaching 9 cm), cylindrical near the base, becoming complanate upwards, repeatedly (usually 4–5 times) dichotomously or rarely trichotomously branched in the same plane with wide angle, usually branching




Text-fig. 5. a. *Gelidopsis hachijoensis* YAMADA et SEGAWA. x 1.
b. Cross section of a branch. x 260.

occurring more often in the upper portion of the frond than in the lower portion but rarely the reverse, sometimes provided with some not long, patent, pinnately arranged branchlets, often entangling, rarely anastomosing with each other, at the extremity attenuated, usually ending in a rounded apex, but sometimes becoming long, thin, cylindrical, often arcuate filaments, but not forming a palmate expansion as seen in *G. repens*. Long cells of small diameter in the medula very few in number, those and the surrounding cells arranged loosely, forming small intercellular spaces here and there; no kind of reproductive organ is known.

It seems to the authors that the habit and the anatomical structure of the present alga indicate its being a species of *Gelidiopsis* although no kind of reproductive organ is known.

Among the described species of this genus. *G. repens* (KG.) SCHMITZ stands nearest to this new species. The two species show characters in common in having complanate fronds which ramify repeatedly di-or trichotomously in the same plane. But in *G. hachijoensis* the ultimate branches do not show the palmate expansion very common in *G. repens*. Instead of this, in the former species some pinnate branchlets are not rarely found along the main branches; these do not seem to be common in the latter species. In anatomical structure the scantiness of the thinner cells in the center, and loose arrangement of the medullary cells near the center of the frond are very peculiar to the new species.

4. *Laurencia amabilis* YAMADA sp. nov. (Text-figs. 6-7) Frons erecta, dense caespitosa, gloma laxa 5-10 cm diam. formans, radice tenuissima parva confluente adfixa, 5-6 cm alta, teres tenuis filamentosis ca. 10 mm crassa, irregulariter alternatim p tenteque quoquoversum ramosa, partis superioribus frondium et ramis saepe arcuatis; ramulis ultimis clavatis, 1-2 mm longis, apice truncatis vel obtusis, vel brevioribus verrucaeformibus; cellulis superficialibus non projicientibus, in sectionibus evidenter radiatim elongatis, 32-48$\mu$ longis, simili modo ut cellulis valliformibus dispositis; cellulis medularibus partem incrassatam lenticulatam ad parietem non ostendentibus; tetrasporangiis prope apicem ramulorum ultimorum verrucaeformium productis; cystocarpiis et antheridiis ignotis.

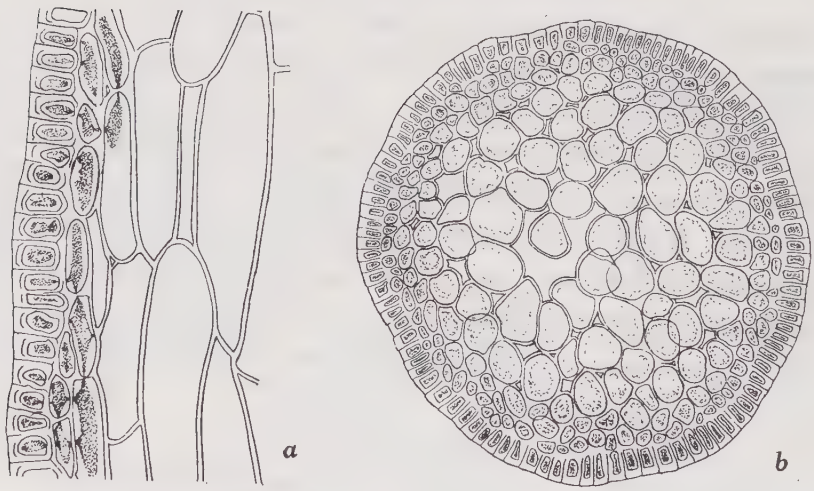
Japanese name; Shima-sozo.

Loc.: Taredo, Yaena and Borawazawa, Hachijo Isl.

Frond erect, densely caespitose, forming a loose glome 5-10 cm in diam., attaching to the substratum by means of a very thin, small holdfast confluent to each other and never forming creeping rhizoidal filaments, 5-6 cm high, terete, filamentous, thin, about 1 mm thick, sending off patent branches irregularly alternately in all

directions, upper parts of the fronds and branches often arcuate, ultimate branchlets clavate, 1-2 mm long, truncate or obtuse at apices, or shorter. Epidermal cells not projecting in the surface view, in both transverse and longitudinal sections radially elongated, 32-48$\mu$ long, 1.5-2 times as long as broad, arranged palisade-like, without lenticular thickenings in the wall of medullary cells. Tetrasporangia produced around near the top of the ultimate branchlets or of wart-like or slightly longer branchlets. Cystocarps and antheridia unknown.

Text-fig. 6. *Laurencia amabilis* YAMADA. x 1.




Text-fig. 7. *Laurencia amabilis* YAMADA. a. Longitudinal section of a branch. x 185.
b. Cross section of a branch. x 90.

Judging from the structure of the frond, the present species belongs to Sect. Palisadae, and seems to relate most closely to *L. Yamada* HOWE from Hawaii. But it can be distinguished from the latter by the erect frond and less divaricate branches.

# NOTES ON THE FLYING-FISHES OF HACHIJO ISLAND, WITH NOMENCLATORIAL REMARKS ON THE FLYING-FISHES OF THE MAINLAND OF JAPAN AND HOKKAIDO. I. "TOBI-UO", *PROGNICHTHYS AGOO**

T. ABE

Tokai Regional Fisheries Research Laboratory and Zool. Inst., Fac. Sci., Tokyo Univ.

Among the fishes of Hachijo Island, some species of the flying-fishes (*Exocoetidae*) are economically most important for the people of the island. The amount of the yearly catch of these fishes**, and more especially of the "Haru-tobi" (meaning spring flying-fish), is said to affect the welfare of the people during the year. Investigations into the biology of the flying-fishes have naturally been conducted by the Fisheries Experiment Station of Tokyo Prefecture and its Hachijo Branch†, but lack of taxonomic knowledge of the flying-fishes of the western Pacific has precluded progress in their studies.

The flying-fishes dealt with in the elaborate works by Drs. BREDER, BRUUN,

* Contributions from the Tokai Regional Fisheries Research Laboratory, B No. 98.

** A considerable quantity of flying-fishes is consumed by fishermen and their friends without being passed through the markets of Hachijo Island. The following catch records gathered by the Division of Fisheries, Hachijo Branch Office, Tokyo Prefectural Government, and Hachijo Branch Station of the Fisheries Experiment Station of Tokyo Prefecture do not include the amount of flying-fishes for such usage:

Catch records of the flying-fishes at Hachijo Island (in metric tons)

| Year | Spring flying-fish | | | | Summer flying-fish | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | |
| 1947 | | | | | | | | | 193.6 |
| 1948 | | | | | | | | | 379.9 |
| 1949 | | | | | | | | | 199.9 |
| 1950 | | 184.9 | 554.5 | 74.9 | | 0.7 | 4.9 | 4.7 | 824.6 |
| 1951 | 0.4 | 109.4 | 250.5 | 36.9 | | | 2.2 | 3.7 | 401.1 |
| 1952 | | 20.8 | 194.9 | 120.2 | 1.5 | 10.3 | 6.5 | 1.2 | 355.4 |

The number of the fishing boats for flying-fishes was 65 in 1950, 1951 and 1952, respectively.

† Hachijo Island is a part of Tokyo Prefecture.

HUBBS, KAMPA and NICHOLS were primarily those of the Atlantic and eastern Pacific, and many of the Japanese ichthyologists, with the exception of Prof. Sadahiko IMAI of Kagoshima University, seem to have paid little attention to these works, which, however, have really established a solid base for the study of the flying-fishes of the western Pacific as well. Furthermore, Dr. BOESEMAN published in 1947 a photograph of the original figure of *Exocoetus agoo* TEMMINCK et SCHLEGEL, and thus the present writer, assisted by the works mentioned above, has been enabled to perceive several common species of flying-fishes of Hachijo Island. The majority of them are also common along the Pacific coasts of the southern parts of the mainland of Japan, and some are met with even near Hokkaido. In a series of papers beginning with the present one, he wishes to give some notes on the flying-fishes of Hachijo Island, with special reference to the scientific names of the common ones in the hope that they might supplement the long-term researches by Dr. BRUUN and Prof. S. IMAI into the life-history, ecology and classification of the flying-fishes of the western Pacific and the studies which are being continued by fishery scientists on these fishes of Hachijo Island and several prefectures of southern Japan where they are of considerable economic importance.

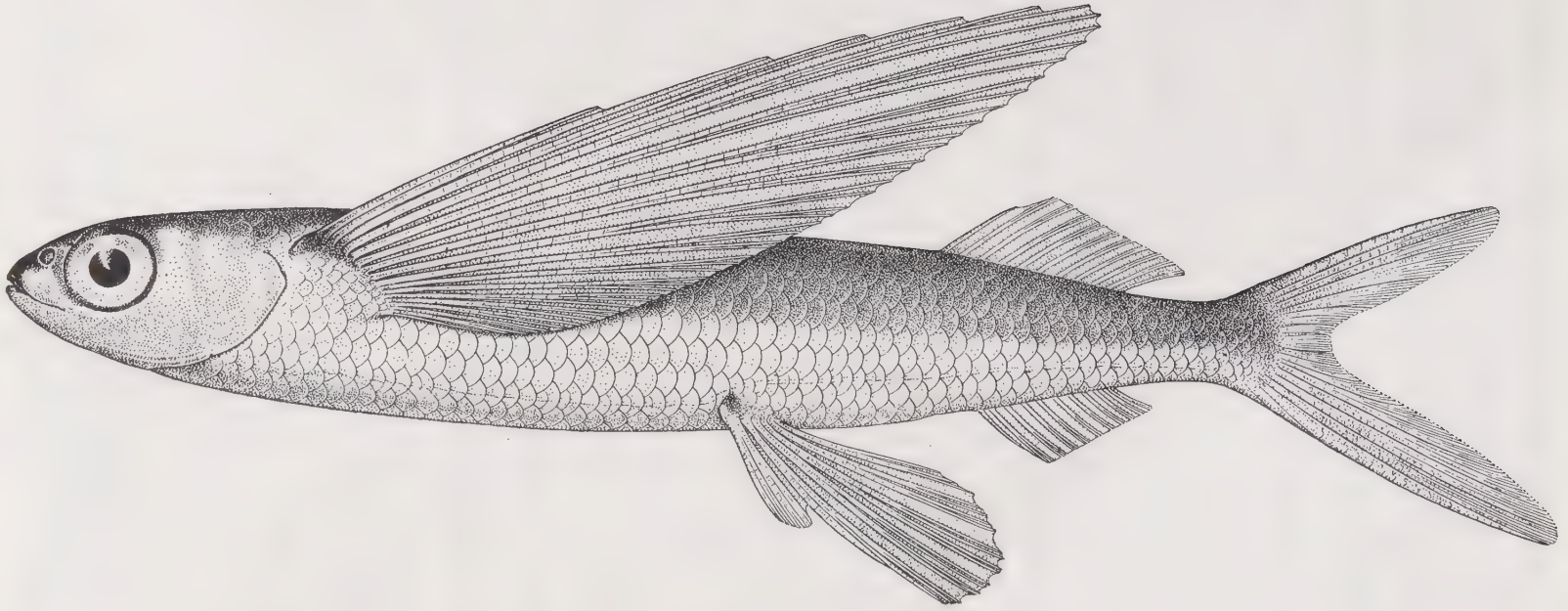
## *Prognichthys agoo* (TEMMINCK *et* SCHLEGEL)

**Plate I**

**"Tobi-uo" or "Tobi," meaning flying-fish (Tokyo);**
**"Ao-tobi," meaning blue flying-fish (Hachijo I.)**

As the original description of *Exocoetus agoo* was based on a Japanese drawing and a short description by BURGER (written BÜRGER by TEMMINCK and SCHLEGEL), much confusion has arisen as to the usage of this specific name. The majority of later authors have adopted the name for a species of *Cypselurus*, and a few authors regarded *agoo* as a doubtful species. So far as the present writer is aware, the report of JORDAN and SNYDER (1901) was the second to record the occurrence in Japanese waters of a flying-fish having two unbranched fin-rays above in the pectoral. They wrote under the heading of *Cypselurus agoo* as follows: "A second species of *Cypselurus*, probably undescribed, has fewer scales in lateral line (46), the first and second pectoral rays short and simple, the third branched." Their specimens were collected in Tokyo. It is highly probable that the species was *Prognichthys agoo*, because the adult of the other species of flying-fishes having two uppermost unbranched fin-rays in the pectoral seem to be rare or absent in Japanese waters. It was not until July 1952, that a detailed account of *Prognichthys agoo* was given by Prof. IMAI under the name of *Prognichthys* sp., with photographs of the adult and young as well as a drawing of the young. He has been very careful in identifying the Japanese flying-fishes, probably because of the lack of some essential details in their original descriptions.

Plate I. *Prognichthys agoo* (TEMMINCK et SCHLEGEL) from Hachijo I. Total length *ca.* 330 mm. Drawing by M. SHIRAO



As STEINDACHNER (in STEINDACHNER and DÖDERLEIN, 1887, p. 39) pointed out, the original drawing of *agoo* in MS. of BURGER is not an exact one; the position of the lateral line, the position of the first anal fin-ray and the total number of the pectoral fin-rays seem not to have been correctly shown in the drawing. But the first and second fin-rays from above of the pectoral are depicted as unbranched rays, although the relative length of the fin-rays of this fin seems not to have been exactly shown. Whether the second fin-ray from above of the pectoral is branched or unbranched can hardly be overlooked by observers who expand the fin of fresh specimens, and the present writer regards this point as the most helpful key to the understanding of the drawing in MS. of BURGER. In the other (probably Japanese) flying-fish with uppermost two unbranched fin-rays in the pectoral, which may be referred to *Danichthys rondeletii* (VALENCIENNES), the color of the pectoral fin and the relative positions of the first anal fin-ray and the first dorsal fin-ray are unmistakably different from those of *Prognichthys agoo*.

There is another unfavorable situation affecting the identification of *Prognichthys agoo*. Pioneers of Japanese ichthyology often mentioned about the fishing seasons or the abundance of the flying-fishes in certain seas or at some markets. But, besides the common flying-fishes with very remarkable markings of the pectoral fin, there are at least five economically important species of flying-fishes, of which one is the giant, *Cypselurus pinnatibarbatus japonicus* (FRANZ). Of the remaining four species, three with a single unbranched fin-ray above in the pectoral were described or figured by JORDAN and STARKS (1903) and their followers as *Cypselurus agoo* without being distinguished from one another*; and the rest is *Prognichthys agoo* (TEMMINCK et SCHLEGEL), which has two unbranched fin rays above in the pectoral. The fish-dealers do not distinguish the four species from one another, whereas *Cypselurus pinnatibarbatus japonicus* (FRANZ) is usually priced by them higher than the former four species and bears the name of "Kaku-tobi," meaning flying-fish with angular head or angular body.

Aided by a grant-in-aid for fundamental scientific research of the Department of Education, the writer had an opportunity to see the catching of the "summer flying-fish" by a drifting gill-net 1/2 to 1 miles off the south-western coast of Hachijo Island on August 25, 1952**. He saw some 1500 living flying-fishes taken by the net on that day. During the subsequent two days he saw thousands of flying-fishes at Yaene Harbor, Hachijo Island, which were taken by the same net off the western

* These three species will be dealt with elsewhere.

** During August 24–30, 1952, the weather at Hachijo Island was very fine and it was very hot. The surface temperature of the sea water at the fishing grounds for the flying-fishes was approximately 29° C in the daytime.

coast of the island. The "summer flying-fish" taken commercially there represented at least five species, of which *Prognichthys agoo* and *Cypselurus poecilopterus* were predominating in number over the others. The former species was shipped in considerable quantity to Tokyo Central Wholesale Market from near the Pacific coast of southern Bōsō Peninsula and from near the southern coast of Kii Peninsula in September, 1952. According to Prof. IMAI, this species is taken commercially by long lines or drifting gill-nets during September—November near the coasts of southern and south-eastern Kyushyu.

**Additions to the description given by Prof. IMAI:** *Vertebral column, interneural and interhaemal spines.* The total number of the vertebrae is 47 (=31 +16 in 5 specimens; 32+15 in 2 specimens; 31+16 or 32+15 in 1 specimen, anterior haemal arches being damaged) or 46 (=31+15 in 1 specimen). In this respect the present species is far from *Prognichthys gibbifrons* (VALENCIENNES) in which, according to Dr. BRUUN ('35), the total number of the vertebrae is 42 (=26+16) or 43 (=27+16 or 28+15).

The number of the interneural spines is 11 in 7 specimens and 12 in 1 specimen. The first interneural has a pair of horns directed forward at its antero-dorsal corner; the last interneural has also a pair of horns at its postero-dorsal corner which are directed backward. The position of the first interneural is between the neural spines of the 27th and 28th vertebrae in 6 specimens and between the neural spines of the 26th and 27th vertebrae in 2 specimens. Correlated with the position of the first interneural spine, the relative length of the neural spine becomes abruptly smaller at the 28th or 27th vertebra. The position of the last interneural is between the neural spines of the 37th and 38th vertebrae in 7 specimens and between the neural spines of the 36th and 37th vertebrae in the one specimen in which the first interneural is between the neural spines of the 26th and 27th vertebrae. In this specimen the 2nd and the 3rd interneurals are inserted between the neural spines of the 28th and 29th vertebrae and there is no interneural spine between the neural spines of the 27th and 28th vertebrae. In all the other specimens the interneural is regularly 1 in number, between the neural spines of two successive vertebrae.

The number of the interhaemal spines is 10 in 7 specimens (of which the number of the anal fin-rays is 10 in 6 specimens and 11 in 1 specimen) and 11 in 2 specimens (of which the number of the anal fin-rays is 11). There are 3 interhaemals lying anteriorly to the first haemal arch in 4 specimens and 4 interhaemals at the same place in 3 specimens. The last interhaemal is between the haemal spines of the 37th and 38th vertebrae in 7 specimens and between the haemal spines of the 36th and 37th vertebrae in 1 specimen. The last interhaemal has a pair of

Table 1. List of the specimens examined of *Prognichthys agoo*

| Number of specimens | Total length* (mm) | Fork length (mm) | Standard length (mm) | Weight (g) | Sex | Maturity | Locality** | Date of collecting, and remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | *ca.* 345 | 292 | 273 | 275 | ♀ | Diameter of eggs 0.8–1.2 mm | Manazuru, Sagami Bay | Oct. 5, '52. Taken by a trap net along with other flying-fishes |
| 11 | *ca.* 320–*ca.* 355 | 280–295 | 262–275 | 240–330 | ♂ 2<br>♀ 5<br>? 4 (not dissected) | Diameter of eggs 0.7–1.3 mm | Tokyo Market (from Katsu-ura, Chiba Prefecture) | Sept. 4, '52 |
| 10 | *ca.* 315–*ca.* 365 | 274–310 | 258–291 | 240–355 | ♂ 6<br>♀ 4 | Diameter of eggs 1.0–1.5 mm | Tokyo Market (from Kushimoto, Wakayama Prefecture) | Sept. 11, '52 |
| 1 | 53 | 46 | 42 | | | | Kurose Bank, northwest of Hachijo I. | Late in Sept., '25. Picked up in the night from the deck of a fishing boat |
| 8 | *ca.* 330–*ca.* 340 | 270–283 | 260–270 | 220–230 | ♂ 8 | Just after breeding | Off southwestern coast of Hachijo I. | Aug. 25, '52 |
| 1 | | 293 | 273 | | | | Off west coast of Hachijo I. | Aug. 26, '52 |
| 5 | *ca.* 310–*ca.* 350 | 260–297 | 245–284 | 200–300 | ♂ 2<br>♀ 3 | Diameter of eggs *ca.* 1.0 mm | Akamizu, Nebeoka City. Taken by a trap net | Early in Nov., '52 |
| 1 | | 270 | 255 | | | | Okinawa I. | |
| 2 | | 265, 270 | 252, 253 | | | | Yaeyama Is. of the Ryukyu Is. | |
| 2 | | 265, 280 | 250, 260 | | | | Ryukyu Is. | |

* Measured from the most anteriorly projecting part of the head to the farthest tip of the caudal fin.

** Arranged from the north to the south.

horns directed backward at its postero-ventral corner, and is much shorter than the similar horns of the last interneural. The number of the interhaemals between the haemal spines of two successive vertebrae is either 1 or 2 (oftener 1).

*Visible portion of dorsal and anal fins.* In the adult, the anal fin is whitish and transparent, and the dorsal is light brownish grey, usually blackish at the distal part of its hind portion (which is not shown in the accompanying plate). The 1st anal fin-ray is below the interspace between the 2nd and 3rd dorsal fin-rays in 1 specimen, below the 3rd dorsal fin-ray in 4 specimens, below the interspace between the 3rd and 4th dorsal fin-rays in 13 specimens, below the 4th dorsal fin-ray in 1 specimen, and below the interspace between the 4th and 5th dorsal fin-rays in 5 specimens. The base of the last anal fin-ray is a little further forward in position than the base of the last dorsal fin-ray.

The number of the dorsal fin-rays is never smaller than the number of the anal fin-rays. The frequency distribution of these numbers is shown in Table 2.

Table 2. Frequency distribution of the number of dorsal fin-rays (D) and that of anal fin-rays (A)

| A \ D | 10 (=i+ 9) | 11 (=i+10) | 12 (=i+11) |
|---|---|---|---|
| 9 (=i+ 8) | 1 (Yaeyama Is.) | | |
| 10 (=i+ 9) | | 15 | |
| 11 (=i+10) | | 9 | 1 |

*Visible portion of pectoral fin.* In the adult there is no marking in the pectoral fin; the color in formalin is bluish grey, a little darker along the upper fin-rays, and the lower part of the fin is lighter. The two uppermost fin-rays are normally unbranched, and much shorter than the 3rd and the next several fin-rays. In only two specimens out of hundreds examined at the market of Yaene, Hachijo I., the pectoral had a single unbranched fin-ray above (on the right in one specimen and on the left in the other), but the relative length of the 2nd fin-ray from above in

Table 3. Frequency distribution of the number of pectoral fin-rays (P)

| | | | | | |
|---|---|---|---|---|---|
| P {Left / Right | 16 (=ii+14)<br>16 (=ii+14) | 16 (=ii+14)<br>17 (=ii+15) | 17 (=ii+15)<br>17 (=ii+15) | 17 (=ii+15)<br>17 (=i +16) | 17 (=i +16)<br>17 (=ii+15) |
| Number of specimens | 3 | 3 | 13 | 1 | 1 |
| P {Left / Right | 16 (=ii+14)<br>18 (=ii+16) | 18 (=ii+16)<br>17 (=ii+15) | 18 (=ii+16)<br>18 (=ii+16) | 19 (=ii+17)<br>18 (=ii+16) | |
| Number of specimens | 1 | 3 | 3 | 1 | |

both specimens was similar to that of the usual specimens. The 2nd fin-ray in both the abnormal fins was branched for only a short distance, in one proximally, and in the other distally. The frequency distribution of the number of the pectoral fin-rays is shown in Table 3.

*Number of caudal fin-rays.* The number of the central branched fin-rays of the caudal in 6 specimens is 6 above and 7 below; the number of the unbranched fin-rays is 6 to 8 above, and 7 to 9 below. In 3 specimens the fin-formula of the caudal is vii/6/7/viii.

*Number of scales.* The number of scales is difficult to count except for the predorsal scales. The scales, especially those along the lateral line, are deciduous, and the arrangement of the scales near the lateral line is irregular. The frequency distribution of the number of predorsal scales counted from the scale just above the pair of posteriorly projecting horns of the supra-occipital to the smaller one covering the basal part of the first dorsal fin-ray is shown in Table 4.

Table 4. Frequency distribution of the number of predorsal scales

| Number of predorsal scales | *ca.* 33 | 33 or 34 | 34 | 34 or 35 | *ca.* 35 | 35 | 35 or 36 | 36 | *ca.* 37 | 38 |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of specimens | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 2 | 1 | 1 |

*Number of branchiostegals.* The left branchiostegal membrane covers the right one anteriorly, and the number of the branchiostegals seems to be higher in the former than in the latter as is seen from Table 5.

Table 5. Frequency distribution of the number of branchiostegals (BR)

| BR | {Left<br>{Right | 10<br>10 | 11<br>10 | 11<br>11 | 12<br>10 | 12<br>10<br>or<br>11 | 12<br>11 |
|---|---|---|---|---|---|---|---|
| Number of specimens | | 1 | 1 | 1 | 2 | 1 | 1 |

*Number of gill-rakers on the first gill-arch.* The frequency distribution of the number of the gill-rakers on the first gill-arch is shown in Table 6.

Table 6. Frequency distribution of the number of the gill-rakers on the first gill-arch (GR)

| GR | {Left<br>{Right | 5+15<br>5+14<br>or<br>5+15 | 6+14<br>6+15 | 6+15<br>5+15 | 6+15<br>5+16 | 6+16<br>6+16 | 7+16<br>6+15 | 7+18<br>7+18 |
|---|---|---|---|---|---|---|---|---|
| Number of specimens | | 1 | 1 | 1 | 1 | 2 | 1 | 1 |

*Other external features of the adult.* The length of the pectoral and ventral fins is not very great; the posterior end of the pectoral reaches a little beyond, or does not reach, the base of the last dorsal fin-ray, and the posterior end of the ventral reaches the base of the penultimate anal fin-ray at the most.

The eye is large, 6.2 to 7.1% of the standard length.

The distance between the anterior end of the head and the insertion of the ventral fin is 53.3 to 60.9% of the standard length.

**Remarks on taxonomic position:** In the absence of detailed osteological studies of the majority of the flying-fishes of the world, the writer feels hesitant to make a statement, but it may be suggested that the present species is far from *Prognichthys gibbifrons* (VALENCIENNES) and nearer to *Danichthys* or *Hirundichthys* in some of its meristic characters, and to some species of *Cypselurus* in the presence of a pair of flaps of skin on the lower jaw in the young. The adoption here of the generic name *Prognichthys* for *agoo* is only provisional.

## *References*


Lack of space has precluded the inclusion of the titles of those papers referred to by Dr. TANAKA, 1931 ("On the distribution of fishes in Japanese waters") and those referred to by Dr. BREDER, 1938 ("A contribution to the life histories of Atlantic ocean flyingfishes).

BOESEMAN, M. 1947. Revision of the fishes collected by BURGER and VON SIEBOLD in Japan, viii +242 pp., 5 pls. Leiden.

FOWLER, H. W. 1932. A synopsis of the fishes of China. Part IV. The Hong Kong Naturalist, iii, pp. 247–279.

—— 1944. Results of Fifth George VANDERBILT Expedition (1941). (Bahamas, Caribbean Sea, Panama, Galapagos Archipelago and Mexican Pacific Islands.). Acad. Nat. Sci. Philad. Monogr. no. 6, viii+583 pp., 20 pls.

—— 1949. The fishes of Oceania-Supplement 3. Mem. B. P. Bishop Mus., xii, no. 2, pp. 35-186.

HERRE, A. W. C. T. 1945. Additions to the fish fauna of the Philippine Islands. Copeia, 1945, pp. 146–149.

HUBBS, C. L. and KAMPA, E. M. 1946. The early stages (egg, prolarva and juvenile) and the classification of the California flyingfish. Copeia, 1946, pp. 188–218, pl. 1.

IMAI, S. 1952. Tobiuo-rui no kenkyu. II. Nihon-san *Prognichthys* zoku no tobiuo to sono yoki (meaning studies on the flyingfishes. II. Japanese flyingfish of the genus *Prognichthys* and its young stages). Kagoshima-daigaku Suisan-gakubu Kiyō, ii, no. 1, pp. 141–148, 1 pl.

POLL, M. 1949. Résultats scientifiques des croisières du Navire-École Belge ((Mercator)), iv, poiss., pp. 173–269.

SCHULTZ, L. P. 1943. Fishes of the Phoenix and Samoan Islands collected in 1939 during the expedition of the U. S. S. "Bushnell". U. S. Nat. Mus. Bull., 180, x+316 pp., 9 pls.

# MOLLUSCAN FAUNA OF HACHIJO-JIMA

## Preliminary report

ISAO TAKI

Zoological Section, National Science Museum, Tokyo

A lot of specimens of marine mollusks were collected from Hachijo-jima during the years from 1950 to 1952. Of these specimens, 467 species were determined provisionally, leaving some undetermined species. The faunistic characteristics of the marine mollusks in Hachijo-jima will be summarised preliminarily in the following lines.

1. *Faunistic composition of marine mollusks.* The marine mollusks of Hachijo-jima are composed of 14(3%) Chitons, 400(86%) Gastropoda, 50(10.4%) Pelecypoda and 3(0.6%) Cephalopoda, as shown in Table 1.

Table 1

**Comparison between the whole of Japan and Hachijo-jima in specific composition of marine mullusks. No. Sp.—number of species; diff.—difference between percentages of all Japan and Hachjjo-jima.**

| Group | Whole Japan | | Hachijo-jima | | diff. % |
|---|---|---|---|---|---|
| | No. Sp. | % | No. Sp. | % | |
| Chitons | 87 | 2.3 | 14 | 3.0 | + 0.7 |
| Gatropoda | 2773 | 74.4 | 400 | 86.0 | +11.6 |
| Pelecypoda | 744 | 20.0 | 50 | 10.4 | − 9.6 |
| Cephalopoda | 125 | 3.3 | 3 | 0.6 | − 0.3 |
| | 3729 | | 467 | | |

The Japanese seas appear to contain about 3729 species of marine mollusks, exclusive of Scaphopoda, composed of 2.3% Chitons, 74.4% of Gastropoda, 20% Pelecypoda and 3.3% Cephalopoda.

As compared with this whole Japanese composition, Hachijo-jima is exceedingly rich in species of Gastropoda, being in excess by 11.6% of the whole Japanese Gastropoda. The Chitons of Hachijo-jima exceed a little that of the whole Japan total, whereas the Pelecypoda of Hachijo-jima are less than a half of the whole Japan in ratio. In the Cephalopoda, the ratio of Hachijo-jima is nearly equal to that of

the whole country.

Hachijo-jima is very poor in species of Pelecypoda and devoid of Scaphopoda, because the island does not furnish so favorable a home for these groups of mollusks, which chiefly inhabit sandy or muddy shores. On the other hand, Chitons and Gastropoda are more or less rich here in the numbers of species, since there are plentiful habitats of rocky shores surrounding the island. Thus the faunistic composition may be peculiar to this island.

2. *Peculiarities in range of distribution.* Of 467 species, 6 Gastropoda are endemic and the other species are divisible into 4 groups in their distribution as shown in Table 2.

Table 2

Specific composition in distribution of Hachijo-jima.
No. Sp.—number of species.

| Lat. N. | Group | No. Sp. | % |
|---|---|---|---|
| 0° −31° | tropical | 55 | 11.9 |
| 0° −36° | warm current | 329 | 71.5 |
| 31°−40° | temperate | 39 | 8.4 |
| 0° −60° | wide ranged | 38 | 8.2 |
| | endemic | 6 | |
| | | 467 | |

The fauna of Hachijo-jima may be considered as situated between the tropical and the temperate groups, comprising a decided mixture of the former and the latter, but the tropical group exceeds the temperate group by 3.5%. Thus the island shows a more tropical than temperate nature in its fauna. However, the warm current group is by far the most prevalent in the fauna of the island.

The warm Kuroshio current, sweeping up between Hochijo-jima and Mikura- jima, seems to permit the purely tropical species to extend to this island, which is much farther north than the shores of Shikoku and Kyushu which show corresponding fauna. Thus Hachijo-jima is situated immediately north of lat. 33°N, but it contains 55 tropical species, which are only known from the southern region of lat. 31°N.

# THE PELAGIC COPEPODS OF THE IZU REGION

O. TANAKA
Faculty of Fisheries, Nagasaki University and Faculty of
Agriculture, Kyūshu University

1. *Introduction.* The present paper is the result of a study of the pelagic Copepoda, Calanoida, collected in the Izu region during the years 1936 to 1940. The first vertical haul from the depth 500 m to 250 m in Suruga Bay, brought up some interesting species which had never been obtained in the surface layer. The present collection was carried out, following the first deep water haul, in the sea area surrounding the Izu Peninsula. 135 vertical hauls were made, chiefly from the depth 1000 m to the surface. Quantitative vertical collections were also taken at different depths with a closing net of 60 cm. in diameter, but they convinced the author that the materials are not sufficient to give a good representation of the vertical distribution of the animals, and a good deal of further study is necessary. There have also been examined some surface collections taken during the years 1930 to 1936 at Misaki, Sagami Bay.

The work was commenced at the Misaki Marine Biological Station connected with the Fishery Department of Tokyo Imperial University, and completed at the Mitsui Institute of Marine Biology in the year 1941.

Before going further the author wishes to express his hearty gratitude to Prof. Dr. Amemiya for his kind encouragement rendered during the study. It is also a great pleasure to extend my best thanks to Mr. T. N. Mitsui, the founder of the Institute, for affording me the opportunity of studying the Copepoda of the Izu region.

It will be a pleasure to me if the present study can add some to the knowledge of the geographical distribution of these small animals.

The Izu region lies in the sub-tropical region of the North Pacific, and is near the latitude where the northern and southern currents meet and overlap, so the material consists of four distinct faunas: the first of them is the endemic species of the area itself; the second is the southern species brought up by the warm Kuroshiwo-current; the third is the northern species brought down by the cold Oyashiwo-current; finally there are in the deeper layers the copepods with a wide range of

geographical distribution. The warm water species of the neighbouring waters of Japan have been nearly completely investigated, and proved to be much like those in other regions of the oceans. In the Izu region, while the warm water species are confined to the upper layer, down to 200 m from the surface, the northern cold water species are obtaind chiefly from the deep layer below 200 m; that is the northern cold water masses brought southwards by the Oyashiwo-current carry with them some boreal species into the intermediate layer of the Izu region, such as *Calanus cristatus* Kroeyer, *Metridia lucens* Boeck and *Metridia longa* Lubbock. The species inhabiting the deep waters are, as F. Dahl stated, completely or nearly completely alike in all the oceans; some of them which have been esteemed to be the characteristic fauna of the Antarctic were proved to be common in the deep waters of the oceans: for instance, *Drepanopsis frigidus* Wolfenden, *Cephalophanes frigidus* Wolfenden, *Scaphocalanus impar* Wolfenden, *Scolecithricella glacialis* Giesbrecht, *Isochaeta ovalis* Giesbrecht have been detected in the present collection. Indeed, a great majority of copepods are cosmopolitan; a wide distribution is the rule rather than the exception.

2. *Material and Method.* The present material was collected in Sagami and Suruga Bays from a small collecting boat, equipped with a wire rope of 4 mm in diameter, and 2,000 m in length. 135 vertical hauls, chiefly from the depth 1,000m to the surface, were made in the 4 stations as given below:

| | | | |
|---|---|---|---|
| Station A | 35°02′N | 139°15′E | Sagami Bay, 8 miles east of Ajiro |
| Station B | 34°40′N | 139°10′E | 9 miles east of Shimoda |
| Station C | 34°36′N | 138°35′E | Suruga Bay, 13 miles west of Irô-saki |
| Station D | 34°58′N | 138°42′E | Suruga Bay, 4 miles west of Heda |

The nets used in the collections were made of stramin, and coarse silk with 29 meshes to a centimeter. The nets were 100 cm. and 60 cm. in diameter respectively; the small one had a closing apparatus.

The gatherings made by the closing net were counted in most cases, while those made with the larger instrument were looked through and only the scarce species were estimated.

3. *Systematic List of the Species.* Up to the present time our knowledge of the copepods of Japanese waters has been limited to the species living in the upper layers of the ocean, and is included in the following papers:

Marukawa, H. (1908). From off the coast of Prov. Boshu, Izu and Suruga.
Marukawa, H. (1921). From the northern waters of Japan.
Marukawa, H. (1928). From the Japan Sea.

Mori, T. (1937). From the neighbouring waters of Japan.
Sato, Ch. (1913). From the neighbouring waters of Hokkaido.
Tanaka, O. (1935). From Sagami Bay.
Tanaka, O. (1935). From Suruga Bay.
Tanaka, O. (1938). From Sagami Bay.
Yamada, T. (1933 and 1935). From the neighbouring waters of Chosen.

Among these, Mori's work includes almost all the surface-living species of Japanese waters. My previous works on Sagami and Suruga Bays include 23 species of Calanoida, of which 5 have been reported by Mori and others, and if the remaining 18 species are added to the 130 species recorded by Mori and others, they bring the total number of Copepods, Calanoida in Japanese waters to 148 species up to that time.

In addition to the above accounts dealing with the copepods of Pacific waters we have the following reports:

Esterly, C. O. (1905, 1906, 1911, 1913, 1924). From the San Diego Region.
Johnson, M. W. (1936). From the North Pacific.
Johnson, M. W. (1938). From the Northeast Pacific.

Finally we have the reports of the "Siboga" collection in the Malay Archipelago which lies midway between the Pacific and Indian Oceans. The report of Calanoida of the Indian Seas by Sewell is one of the most complete ones. Then we have copepods of the South Pacific reported by Farran from the Great Barrier Sea. These three works contain very interesting suggestions concerning the distribution of the copepods in the Pacific Ocean.

In the following is given a systematic list of the species belonging to the Suborder Calanoida obtained in the present collection, and the species hitherto recorded from Japanese waters. (The latter is marked with an asterisk)

Tribe Ampharaskandria

*Family* CALANIDAE

Genus Calanus Leach

*finmarchicus* (Gunners)
*tenuicornis* (Dana)
*tonsus* Brady
*cristatus* Kröyer

**hyperboreus* Kröyer
**plumchrus* Marukawa
*minor* (Claus)

Genus Calanoides Brady

*brevicornis* (Lubbock)

Genus Canthocalanus A. Scott

*pauper* (Giesbrecht)

Genus Neocalanus Sars

*gracilis* (Dana) — *robustior* (Giesbrecht)

Genus Megacalanus Wolfenden

*longicornis* Sars

Genus Undinula A. Scott

*darwini* (Lubbock) — *vulgaris* (Dana)

*Family* EUCALANIDAE

Genus Eucalanus Dana

*attenuatus* (Dana) — *mucronatus* Giesbrecht

*elongatus* (Dana) — *pileatus* Giesbrecht

*bungii bungii* Johnson — *subcrassus* Giesbrecht

*bungii californicus* Johnson — *subtenuis* Giesbrecht

*crassus* Giesbrecht

Genus Rhincalanus Dana

*cornutus* Dana — *nas*utus Giesbrecht

Genus Mecynocera Thompson

*clausi* Thompson

*Family* PARACALANIDAE

Genus Paracalanus Boeck

*aculeatus* Gieshrecht — *parvus* Giesbrecht

*denudatus* Sewell

Genus Acrocalanus Giesbrecht

*gracilis* Giesbrecht — *gibber* Giesbrecht

*longicornis* Giesbrecht — **A. monachs* Giesbrecht.

Genus Calocalanus Giesbrecht

*pavo* (Dana) — *pavoninus* Farran

*plumulosus* (Claus) — *gracilis* sp. nov.

*styliremis* Giesbrecht

*Family* PSEUDOCALANIDAE

Genus Clausocalanus Giesbrecht

*arcuicornis* (Dana) — *pergens* Farran

*furcatus* (Brady)

Genus Ctenoclanus Giesbrecht

*vanus* Giesbrecht

Genus Pseudocalanus Boeck

*minutus* (Kröyer) — **gracilis* Sars

Genus Microcalanus Sars

*pygmaeus* Sars

Genus Mimocalanus Parran

*cultrifer* Farran

Genus Spinocalanus Giesbrecht

*abyssalis* Giesbrecht — *angusticeps* Sars

*spinosus* Farran — *longipes* sp. nov.

*magnus* Wolfenden

Genus Monacilla Sars

*typica* Sars — *gracilis* (Wolfenden)

*typica var, asymmetrica* var. nov.

Genus Drepanopsis Wolfenden

*frigidus* Wolfenden — *orbus* sp. nov.

Genus Ryocalanus gen. nov.

*infelix* sp. nov.

*Family* AETIDEIDAE

Genus Aetideus Brady

*armatus* (Boeck) — *bradyi* A. Scott

*giesbrechti* Cleve — *acutus* Farran

Genus Aetideopsis Sars

*multiserrata* Wolfenden — *divergens* sp. nov.

*cristata* sp. nov.

Genus Undinopsis Sars

**armatus* (Brady) — *angustus* sp. nov.

Genus Chiridius Giesbrecht

*gracilis* Farran — *molestus* sp. nov.

*poppei* Giesbrecht — *cacnosus* sp. nov.

*longispinus* sp. nov. — *carnosus* sp. nov.

Genus Chiridiella Sars

*macrocactyla* Sars — *brachydactyla* Sars

Genus Gaidius Giesbrecht

*tenuispinus* (Sars) — *minutus* Sars

*brevispinus* Sars — *pungens* Giesbrecht

Genus Gaetanus Giesbrecht

*kruppi* Giesbrecht — *miles* Giesbrecht

*armiger* Giesbrecht — *pileatus* Farran

*minor* Farran

Genus Euchirella Giesbrecht

*rostrata* Giesbrecht — *trigrada* sp. nov.

*pulchra* (Lubbock) — *areata* sp. nov.

*messinensis* (Claus) — *curticauda* Giesbrecht

*venusta* Giesbrecht — *bitumida* With

*intermedia* With — *amoena* Giesbrecht

Genus Chirundina Giesbrecht

*streetsi* Giesbrecht

Genus Pseudochrella Sars

*pustulifera* Sars — *dura* sp. nov.

*tuberculata* sp. nov.

Genus Chirundinella gen. nov. — *cara* sp. nov.

Genus Undeuchaeta Giesbrecht

*plumosa* (Lubbock) — *major* Giesbrecht

*magna* sp. nov.

Genus Valdiviella Steuer

*oligarthra* Steuer

*Family* EUCHAETIDAE

Genus Euchaeta Phillipi

*marina* Prestandrea — *plana* Mori

*wolfendeni* A. Scott — *media* Giesbrecht

*longicornis* Giesbrecht — *pubera* Sars

*concinna* Dana — *spinosa* Giesbrecht

Genus Pareuchaeta A. Scott

*russeli* (Farran) — *nitida* sp. nov.

*simplex* sp. nov. — *scotti* (Farran)

*barbata* (Brady) — *crassa* sp. nov.

*malayensis* Sewell — *tonsa* (Giesbrecht)

*confusa* sp. nov. — *elongata* (Esterly)

*calva* sp. nov. — *hanseni* (With)

*aequatorialis* nom. nov. — *comosa* sp. nov.

*bisinuata* (Sars) — *flava* Giesbrecht

*sarsi* (Farran)

*Family* PHAENNIDAE

Genus Phaenna Claus

*spinifera* Claus

Genus Onchocalanus Sars

*affinis* With — *cristatus* (Wolfenden)

Genus Xanthocalanus Giesbrecht

*pinguis* Farran — *legatus* sp. nov.

*profundus* Sars — *penicillatus* sp. nov.

*fallax* — *pectinatus* sp. nov.

*echinatus*

Genus Amallophora T. Scott

*serratus* sp. nov. — *crassirostris* sp. nov.

*cornifer* sp. nov. — *oculatus* sp. nov.

*irritans* sp. nov.

Genus Cornucalanus Wolfenden

*indicus* Sewell

Genus Cephalophanes Sars

*frigidus* Wolfenden

*Family* SCOLECITHRICIIDAE

Genus Lophothrix Giesbrecht

*frontalis* Giesbrecht — *humilifrons* Sara

Genus Undinothrix gen. nov.

*spinosa* sp. nov.

Genus Scottcalanus Sars

*securifrons* (T. Scott) — *longispinus* A. Scott

*helenae* (Lubbock) — *rotundatus* sp. nov.

*australis* Farran

Genus Scaphocalanus Sars

magnus (T. Scott)

*affinis* Sars — *sub-brevicornis* (Wolfenden)

*glacialis* (Giesbrecht) — *macropes* sp. nov.

*elongatus* A. Scott — *echinatus* Farran

*major* (T. Scott) — *curtus* Farran

*impar* (Wolfenden) — *temporalis* sp. nov.

*brevicornis* G.O. Sars. — **pacificus* Mori

*longifurca* (Giesbrecht) — *gracilicauda* Tanaka

Genus Racovitzanus Giesbrecht

*levis* sp. nov. — *nanus* sp. nov.

Genus Scolecithrix Brady

*danae* (Lubbock)
*nicobarica* Sewell

Genus Scolecithricella Sars

*bradyi* (Giesbrecht)
*modica* sp. nov.
**minor* (Brady)
*gracilis* Sars
**orientalis* Mori
*propinqua* Sars
*vittata* (Giesbrecht)
*emarginata* Farran
*abyssalis* (Giesbrecht)
*valida* Farran
*dentata* (Giesbrecht)
*sarsi* nom. nov.
*profunda* (Giesbrecht)
*arcuata* Sars
*longipes* (Giesbrecht)
*lamellifer* sp. nov.
*tenuiserrata* (Giesbrecht)
*spinata* sp. nov.
*beata* sp. nov.
*timida* sp. nov.
*avia* sp. nov.
*denticulata* sp. nov.
*ctenopus* (Giesbrecht)
*lanceolata* sp. nov.
*ovata* (Farran)
*sp.*

*Family* THARYBIDAE

Genus Tharybis Sars

*sagamiensis* sp. nov.

Genus Undinella Sars

*oblonga* Sars
*simplex* Wolfenden
*frontalis* Tanaka
*spinifer* sp. nov.

Tribe Heterarthrandria

*Family* CENTROPAGIDAE

Genus Centropages Herrick

*calaninus* (Dana)
*brady* Wheeler
*gracilis* (Dana)
*abdominalis* Sato
*furcatus* (Dana)
*yamadai* Mori
*orsinii* Giesbrecht
*violaceus* (Claus)
*longicornis* Mori

*Family* DIAPTOMIDAE

Genus Pseudodiaptomus Herrick

**marinus* Sato

*Family* TEMORIDAE

Genus Temora Baird

*turbinata* (Dana)
*discaudata* Giesbrecht
*stylifera* (Dana)

Genus Eurytemora Giesbrecht

**herdmanii* Thompson and A. Scott — **pacifica* Sato

*Family* METRIIDAE

Genus Metridia Boeck

*curticauda* Giesbrecht — *brevicauda* Giesbrecht

*venusta* Giesbrecht — *longa* Lubbock

*princeps* Giesbrecht — *lucens* Boeck

Genus Pleuromamma Giesbrecht

*abdominalis* (Lubbock) — *indica* Wolfenden

*xiphias* Giesbrecht — **robusta* Giesbrecht

*gracilis* Claus

*Family* LUCICUTIIDAE

Genus Lucicutia Giesbrecht

*ovalis* Wolfenden — *flavicornis* (Claus)

*longiserrata* Giesbrecht — *curta* Farran

*sewelli* sp. nov. — *lucida* Farram

*longispina* sp. nov. — *sarsi* nom. nov.

*macrocera* Sars — *wolfendeni* Sewell

*magna* Wolfenden — *maxima* Steuer

*clausi* Giesbrecht — *bicornuta* Wolfenden

Genus Isochaeta Giesbrecht

*ovalis* Giesbrecht

*Family* HETERORHABDIDAE

Genus Heterorhabdus Giesbrecht

*papilliger* (Claus) — *spinifrons* (Claus)

*dubius* sp. nov. — *subspinifrons* sp. nov.

*devius* sp. nov. — *vipera* (Giesbrecht)

*fistulosus* sp. nov. — *compactus* Sars

*vicinus* sp. nov. — *robustus* Farran

*abyssalis* Giesbrecht — *tenuis* sp. nov.

*pilosus* sp. nov.

Genus Heterostylites Sars

*longicornis* (Giesbrecht) — *major* (Dahl)

Genus Hemirhabdus Wolfenden

*grimaldi* (J. Richard) — *latus* Sars

Genus Mesorhabdus Sars

*brevicaudatus* (Wolfenden)

Genus Disseta Giesbrecht

*palumboi* Giesbrecht — *maxima* Esterly

*Family* AUGAPTILIDAE

Genus Euaugattilus Sars

*nodifrons* Sars — *niveus* sp. nov.

*farrani* Sars — *nudus* sp. nov.

*laticeps* Sars — *marginatus* sp. nov.

*filigerus* (Claus) — *bullifer* (Giesbrecht)

*magnus* Wolfenden — *longimanus* Sars

*oblongus* Sars — *hecticus* (Giesbrecht)

*palumboi* (Giesbrecht) — *rigidus* Sars

*facilis* (Farran)

Genus Augaptilus Giesbrecht

*anceps* Farran — *glacialis* Sars

*longicaudatus* (Claus)

Genus Haloptilus Giesbrecht

*longicornis* (Claus) — *spiniceps* (Giesbrecht)

*setuliger* sp. nov. — *ornatus* (Giesbrecht)

*acutifrons* (Giesbrecht) — *longiceps* sp. nov.

*oxycephalus* (Giesbrecht) — **mucronatus* (Claus)

Genus Pseudaugaptilus Sars

*orientalis* sp. nov.

Genus Pachyptilus Sars

*abreviatus* Sars — *pacificus* Johnson

*eurygnathus* Sars

*Family* ARIETELLIDAE

Genus Arietellus Giesbrecht

*simplex* Sars — *giesbrechti* Sars

Genus Paraugaptilus Wolfenden

*buchani* Wolfenden

Genus Phyllopus Brady

*helgae* Farran — *impar* Farran

*bidentatus* Brady — *mutatus* sp. nov.

*Family* CANDACIIDAE

Genus Candacia Dana

*bipinnata* (Giesbrecht)
*pachydactyla* (Dana)
*curta* (Dana)
*aethiopica* (Dana)
*bradyi* A. Scott
*catula* (Giesbrecht)
*truncata* (Dana)
*bispinosa* (Claus)
*longimana* (Claus)
*norvegica* Boeck
*grandis* sp. nov.
**discaudata* A. Scott
**simplex* Giesbrecht
**pectinata* Brady
**pacifica* Mori

*Family* PONTELLIDAE

Genus Calanopia Dana

*elliptica* (Dana)
**thompsoni* A. Scott
*minor* A. Scott

Genus Anomalocera Templeton

**patersoni* Templeton

Genus Labidocera Lubbock

*acutifrons* (Dana)
*acuta* (Dana)
*detruncata* (Dana)
*pavo* Giesbrecht
*kröyer* (Brady)
*minuta* Giesbrecht
*japonica* Mori
*bipinnata* Tanaka
**euchaeta* Giesbrecht
**rotunda* Mori

Genus Pontella Dana

*securifer* Brady
*princeps* Dana
*fera* Dana
*chierchiae* Giesbrecht
*kieferi* Pesta
**longipedata* Sato

Genus Pontellopsis Brady

*regalis* (Dana)
*villosa* Brady
*armata* Giesbrecht)
*yamadae* Mori
**perspicax* (Dana)
**tenuicauda* Giesbrecht

Genus Pontellina Dana

*plumata* (Dana)

*Family* PARAPONTELLIDAE

Genus Bathypontia Sars

*longipes* sp. nov.
*longicornis* sp. nov.
*similis* sp. nov.

*Family* ACARTIDAE

Genus Acartia Dana

*clausi* Giesbrecht
*steueri* Smirnov
*amboinensis* Carl
*pacifica* Steuer
*danae* Giesbrecht
*negligens* Dana
**spinicauda* Giesbrecht
**longiremis* Lilljeborg
**bifilosa* Giesbrecht
**erythraea* Giesbrecht
**hamata* Mori

*Family* TORTANIDAE

Genus Tortanus Giesbrecht

*forcipatus* Giesbrecht
*steueri* sp. nov.
*rubidus* sp. nov.
**discaudatus* Thompson and A. Scott

# INDIVIDUAL DIFFERENCES AND DEGREE OF DIFFICULTY IN AGE DETERMINATION OF SIX FISH SPECIES

Y. HIYAMA, T. KUSAKA and Y. NOSE

Fisheries Institute, Faculty of Agriculture, Tokyo University

1. *Introduction* Very frequently the age determinations of various kinds of fish have been done by many workers, and the results used as the basis for knowledge about the growth, age composition of fish populations and other subjects. However, only in a few of them criticisms on the differences of the results obtained by different observers were made, and many were overlooking the fact that if the same samples are examined by others the result may differ to a certain extent.

The authors thus wanted to know about the extent of differences of the results of age determination made by different persons, because exact knowledge on this point would help in consideration of the data which are available concerning the growth, age composition of the population and other problems of fisheries biology. Therefore, in June of 1952, a class of students taught by the authors were mobilized as the age readers to supply the data for us.

2. *Materials and Method* As the extent of personal differences should vary according to the fish species, having the feature or pattern of scale or otolith different, the following six species were selected to represent the various types. The reason why only one species was selected for otolith reading is that this shows less variation than scale patterns.

(I) 44 scales of the herring, *Clupea pallasi*; (II) 42 scales of the saury, *Cololabis saira*; (III) 41 scales of the common goby, *Acanthogobius flavimanus*; (IV) 43 otoliths of the Japanese sole, *Microstomus kitaharae*; (V) 50 scales of the yellowfin tuna, *Neothunnus macropterus*; (VI) 47 scales of the crucian carp, *Carassius carassius*. These 267 samples were prepared for microscopic observations, each sample set between two slide glasses, merely cleared and not stained, the two ends of the glasses bound by label paper, which had only the number of the sample and the name of the fish species. The same 267 samples were examined under the microscope

by nineteen students in a class laboratory, within two afternoons, (eight hours altogether), having two teachers continually inspecting, pretending that the work is the examination at the end of the Age Determination Course, so as to make them examine sincerely and report the results of observations exactly. These students were in the third year class of the Fisheries Course of Tokyo University, and had been trained in age determination technique for ten afternoon (four hours in an afternoon) exercises in the laboratory, besides a lecture on this subject.

Thus, the results of age determinations on 267 samples of scales and otoliths from six fish species by nineteen persons were obtained by us, and these were analysed as follows.

3. *Personal Differences* (1) As the first step, the data were tabulated as Table 1, which shows the number of persons who read the age as shown in the leftmost column for each sample of scale and otolith as numbered in the uppermost line for each fish species. This apparently shows how the results of age reading by nineteen persons varies in each sample.

(2) As the second step, as shown in Table 2 and Fig. 1, the samples of otolith or scale of each fish species are regarded as being from some fish population, and the result of the age determination by individual person is arranged to indicate the age composition of the population. Thus, Table 2 shows the personal achievements of this sort of age composition for each fish species by each individual observers named by letters. The same data are arranged in Fig. 1 as a graph, each fish kind having nineteen curves of age composition obtained by individual observers. The two arrangements show how largely the individual achievement of age composition of the same samples varies. Among the six fish species, (vd. Fig. 1), the herring has less variation than the others, as its nineteen curves run more closely together.

(3) Since the personal differences are so great, as the next step, Table 3 was prepared to show the frequency of the greatest number of persons among the nineteen, who read the same age for the same samples, based upon Table 1. As Table 3 shows, only one sample among 267 samples was read as the same age by all nineteen persons, and it was one of a herring scale, which has more coincidental cases than others generally. In an extreme case of the Crucian carp, only four of the nineteen obserbers read the same age value on the same sample, and four is the highest value of frequency of the coincidence. This indicates that the personal difference of age determination is more marked than would be thought by common sense.

Table 1. Explanation: See p. 139 (1)

(I) Herring

| Age \ Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — |
| 3 | — | 1 | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | 1 | — | — | — | — | — | 10 | — | 1 | — | — | — | — | — | — | 14 | — | 8 | — | — | — | — | 13 | — | — | — | — | — |
| 4 | 15 | 14 | 17 | 6 | 2 | 8 | 6 | 17 | 6 | 4 | 2 | 6 | 1 | 9 | 3 | 1 | 9 | 12 | 3 | 1 | 12 | 3 | 8 | 13 | 14 | 6 | 15 | 16 | — | 5 | 17 | 14 | 5 | 18 | 8 | 12 | 10 | 19 | 16 | 5 | 12 | 14 | 18 | 9 |
| 5 | 4 | 3 | 1 | 12 | 13 | 9 | 12 | 1 | 13 | 14 | 15 | 11 | 13 | 6 | 5 | 18 | 9 | 5 | 14 | 13 | 7 | 16 | 1 | 6 | 2 | 11 | 4 | 1 | 17 | 14 | 12 | 4 | — | 1 | 2 | 6 | 8 | — | 2 | — | 6 | 4 | 1 | 10 |
| 6 | — | — | 1 | — | 3 | 2 | 1 | 1 | — | 1 | 2 | 1 | 2 | 3 | 7 | — | — | 2 | 2 | 3 | — | — | — | — | 1 | 1 | — | 2 | 1 | — | — | 1 | — | — | — | — | 1 | — | — | 1 | 1 | 1 | — | — |
| 7 | — | 1 | — | 1 | 1 | — | — | — | — | — | — | 1 | 2 | — | 4 | — | — | — | — | 2 | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — |
| 8 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | 1 | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — |

(II) Saury

| Age \ Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — |
| 1 | — | — | — | — | — | — | 2 | 1 | — | 1 | — | 1 | 1 | — | 1 | — | 1 | — | 3 | — | 2 | 1 | — | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | — | 1 | 2 | — | — | — | — | 3 |
| 2 | 2 | 3 | 3 | — | 1 | 1 | 7 | 1 | — | 1 | 2 | 3 | 5 | 5 | 5 | 4 | 5 | 7 | 3 | 6 | 5 | 3 | 5 | 7 | 4 | 2 | 2 | 2 | 2 | 5 | 9 | 3 | 13 | 3 | 6 | 4 | 1 | — | 1 | 11 | 7 | 9 |
| 3 | 13 | 8 | 10 | 6 | 12 | 5 | 10 | 11 | 7 | 6 | 2 | 11 | 9 | 11 | 5 | 11 | 9 | 7 | 8 | 8 | 4 | 8 | 11 | 8 | 10 | 6 | 4 | 6 | 10 | 8 | 5 | 8 | 4 | 11 | 9 | 11 | 10 | 10 | 6 | 5 | 11 | 5 |
| 4 | 2 | 7 | 5 | 10 | 5 | 6 | — | 5 | 9 | 7 | 12 | 4 | 3 | 2 | 6 | 3 | 3 | 4 | 5 | 5 | 8 | 5 | 1 | 2 | 3 | 6 | 6 | 7 | 4 | 3 | 2 | 6 | 1 | 1 | 2 | 2 | 5 | 7 | 10 | 3 | — | 2 |
| 5 | 2 | 1 | — | 2 | 1 | 3 | — | 1 | 2 | 4 | 1 | — | 1 | 1 | 1 | 1 | 1 | — | — | — | 2 | 2 | 1 | — | 2 | 3 | 1 | 1 | 1 | 1 | — | — | 2 | 2 | — | 1 | 2 | 2 | — | — | — | — |
| 6 | — | — | — | 1 | — | 4 | — | — | 1 | — | 2 | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | 1 | 2 | 2 | — | 1 | — | — | — | — | — | 1 | — | — | — | — | 1 | — |
| 7 | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

(III) Goby

| Age \ Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | — | — | — | — | — | — | 1 | 1 | — | — | — | — | — | — | 1 | — | — | — | — | — | 1 | — | 1 | — | — | 1 | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — |
| 1 | 1 | — | 2 | 2 | 2 | 2 | 1 | 1 | 2 | — | 3 | 2 | 3 | 1 | 2 | 4 | 1 | 4 | 4 | 5 | 1 | 6 | 1 | 1 | 1 | 4 | 1 | — | 1 | 3 | 6 | 1 | 3 | 3 | 4 | 2 | — | 3 | 2 | 1 | — |
| 2 | 3 | 7 | 10 | 4 | 4 | 9 | 6 | 7 | 7 | 5 | 4 | 4 | 6 | 4 | 8 | 5 | 6 | 5 | 3 | 11 | 11 | 7 | 8 | 6 | 8 | 2 | 3 | 13 | 2 | 10 | 5 | 9 | 10 | 6 | 11 | 5 | 14 | 5 | 5 | 6 | 15 |
| 3 | 9 | 7 | 5 | 9 | 7 | 7 | 8 | 7 | 7 | 10 | 10 | 8 | 7 | 8 | 6 | 5 | 10 | 9 | 12 | 3 | 5 | 5 | 9 | 10 | 8 | 9 | 10 | 5 | 6 | 4 | 8 | 8 | 4 | 9 | 4 | 12 | 3 | 8 | 9 | 10 | 3 |
| 4 | 5 | 5 | 2 | 3 | 5 | 1 | 2 | 3 | 1 | 4 | 2 | 4 | 3 | 5 | 2 | 5 | 2 | — | — | — | 2 | 1 | 1 | 2 | 1 | 3 | 4 | 1 | 6 | 1 | — | — | 2 | 1 | — | — | 2 | 3 | 3 | — | 1 |
| 5 | 1 | — | — | 1 | 1 | — | 1 | — | 2 | — | — | — | — | 1 | — | — | — | 1 | — | — | — | — | — | — | 1 | — | 1 | — | 4 | 1 | — | — | — | — | — | — | — | — | — | — | 2 | — |
| 6 | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

Table 1. (Continued)

(Ⅳ) Sole (Otolith)

| Age \ Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | 1 | — | — |
| 2 | — | — | — | 2 | — | 2 | — | — | — | 5 | 9 | 3 | 1 | 2 | — | — | 3 | — | 1 | 1 | 3 | 3 | 5 | 4 | 1 | 2 | — | 2 | 2 | — | — | 1 | 5 | 2 | 3 | 1 | — | 2 | 1 | 1 | 1 | — | 2 |
| 3 | 3 | 4 | 5 | 5 | 8 | 13 | 8 | 7 | 13 | 11 | 7 | 3 | 2 | 3 | 3 | 4 | 6 | 2 | 12 | 7 | 5 | 9 | 6 | 8 | 8 | 3 | 7 | 9 | 8 | 4 | 6 | 11 | 5 | 7 | 6 | 9 | 7 | 12 | 10 | 4 | 7 | 10 | 5 |
| 4 | 10 | 10 | 12 | 7 | 6 | 2 | 4 | 7 | 5 | 3 | 1 | 5 | 9 | 8 | 8 | 1 | 7 | 7 | 6 | 5 | 5 | 4 | 4 | 5 | 7 | 9 | 7 | 1 | 5 | 9 | 9 | 7 | 5 | 8 | 4 | 6 | 7 | 5 | 4 | 6 | 5 | 6 | 4 |
| 5 | 5 | 5 | 2 | 2 | 4 | 2 | 5 | 5 | 1 | — | 1 | 5 | 6 | 1 | 6 | 13 | 2 | 6 | — | 5 | 4 | — | 4 | 2 | 3 | 3 | 4 | 6 | 4 | 3 | 3 | — | 3 | — | 4 | 2 | 3 | — | 3 | 5 | 2 | 1 | 5 |
| 6 | 1 | — | — | 2 | 1 | — | 1 | — | — | — | 3 | 1 | 5 | 1 | 1 | 1 | 4 | — | 1 | — | 2 | — | — | — | 2 | 1 | 1 | — | 3 | 1 | — | — | 2 | 2 | 1 | 1 | — | 1 | 2 | 3 | 1 | 2 |
| 7 | — | — | — | 1 | — | — | 1 | — | — | — | — | — | — | 1 | — | — | — | — | — | 2 | 1 | — | — | — | — | — | — | — | — | — | 1 | — | — | — | 1 | — | — | — | — | 1 | 1 |

(Ⅴ) Yellowfin Tuna

| Age \ Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 1 | — | — | 1 | 2 | — | — | — | — | 1 | — | — | 1 | 1 | 1 | — | — | — | — | — | 1 | 1 | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | 1 | — | 1 | — | — |
| 2 | 3 | 1 | 2 | 4 | 3 | 3 | 1 | 2 | 2 | — | 1 | 1 | 9 | 2 | 3 | 3 | 4 | 2 | 2 | — | — | 1 | 2 | 1 | — | — | — | 1 | 1 | 2 | — | — | — | — | — | — | 6 | 4 | 1 | 4 | 1 | 2 | — | 2 | 5 | 2 | 3 | — | — | 4 |
| 3 | 4 | 7 | 3 | 7 | 6 | 3 | 1 | 6 | 6 | 3 | 6 | 4 | 3 | 7 | 8 | 10 | 2 | 2 | 7 | — | 2 | 3 | 6 | 6 | 2 | 8 | 1 | 2 | 4 | 4 | 4 | 1 | 1 | 2 | 2 | — | 8 | 3 | 12 | 11 | 6 | 5 | 5 | 6 | 7 | 5 | 9 | 7 | 8 | 9 |
| 4 | 7 | 7 | 7 | 3 | 5 | 6 | 11 | 5 | 5 | 8 | 4 | 8 | 4 | 5 | 6 | 3 | 9 | 7 | 4 | 6 | 8 | 6 | 3 | 7 | 3 | 7 | 4 | 7 | 7 | 4 | 5 | 4 | 6 | 4 | 11 | 6 | 5 | 6 | 6 | 1 | 9 | 8 | 5 | 6 | 5 | 8 | 5 | 11 | 9 | 6 |
| 5 | 5 | 4 | 5 | 1 | 3 | 6 | 3 | 5 | 2 | 7 | 5 | 4 | 1 | 2 | 1 | 3 | 4 | 3 | 5 | 6 | 6 | 7 | 5 | 5 | 7 | 4 | 6 | 4 | 5 | 6 | 4 | 10 | 5 | 10 | 4 | 7 | — | 6 | — | 2 | 1 | 4 | 4 | 4 | 1 | 4 | 1 | 1 | 2 | — |
| 6 | — | — | 1 | 2 | 2 | 1 | 1 | — | 3 | 1 | 2 | 1 | — | 2 | 1 | — | — | 3 | 1 | 4 | 1 | 2 | 2 | — | 2 | — | 2 | 2 | 2 | 2 | 6 | 3 | 6 | 3 | 2 | 3 | — | — | — | — | 2 | — | 3 | 1 | — | — | — | — | — | — | — | — |
| 7 | — | — | — | — | — | — | 2 | 1 | — | — | 1 | — | — | — | — | — | — | 1 | — | 1 | 1 | — | — | — | 3 | — | 2 | 2 | — | 1 | — | 1 | 1 | — | — | 1 | — | — | — | — | — | — | 2 | — | — | — | — | — | — | — | — |
| 8 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | — | — | — | — | 1 | — | 3 | 1 | — | — | — | — | — | 2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 9 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

(Ⅵ) Crucian carp

| Age \ Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | — | 1 | — | 4 | — | 1 | — | 5 | — | 4 | — | 4 | — | — | — | 1 | — | 3 | — | 3 | — | 3 | 1 | — | — | — | 5 | — | — | — | 3 | — | 4 | — | 3 | 1 | 3 | — | 1 | — | 3 | 1 | 1 | — | 4 | — | — |
| 2 | — | 3 | 2 | 3 | 2 | 2 | — | 1 | — | 3 | — | 3 | — | 6 | 1 | 7 | 1 | 3 | — | 2 | 2 | 1 | 1 | — | 5 | — | — | — | — | — | 2 | 1 | 6 | — | 3 | 1 | 1 | — | 2 | 1 | 2 | 1 | 1 | — | 1 | — | 2 |
| 3 | 2 | 5 | 3 | 2 | 2 | 7 | 3 | 2 | 1 | 8 | — | 1 | 1 | 5 | 4 | 6 | 1 | 7 | 1 | 5 | 2 | 5 | 3 | 2 | 6 | 1 | 4 | 2 | 8 | 4 | 3 | 2 | 5 | 1 | 6 | 8 | 4 | 2 | 7 | — | 5 | 1 | 1 | — | 3 | 5 | 12 |
| 4 | 6 | 6 | 5 | 7 | 11 | 6 | 9 | 5 | 8 | 3 | 8 | 4 | 9 | 5 | 7 | 5 | 4 | 3 | 8 | 3 | 4 | 5 | 6 | 7 | 6 | 8 | 6 | 11 | 7 | 9 | 5 | 4 | 2 | 6 | 6 | 3 | 6 | 8 | 8 | 7 | 3 | 5 | 10 | 4 | 7 | 7 | 5 |
| 5 | 6 | 4 | 7 | 3 | 4 | 2 | 5 | 5 | 7 | 1 | 5 | 4 | 7 | 3 | 5 | — | 8 | 1 | 8 | 4 | 9 | 2 | 6 | 6 | 1 | 7 | 2 | 4 | 3 | 4 | 1 | 6 | 2 | 3 | 1 | 5 | 5 | 7 | 1 | 8 | 5 | 10 | 3 | 10 | 2 | 6 | — |
| 6 | 3 | — | 1 | — | — | 1 | 2 | — | 2 | — | 4 | 2 | 2 | — | 2 | — | 3 | 1 | 1 | 1 | 2 | 2 | — | 3 | 1 | 2 | 2 | 2 | 1 | 2 | 4 | 4 | — | 6 | — | 1 | — | 1 | — | 3 | — | 1 | 2 | 5 | 1 | 1 | — |
| 7 | 2 | — | 1 | — | — | — | — | 1 | 1 | — | 2 | 1 | — | — | — | — | 2 | 1 | 1 | 1 | — | 1 | 2 | 1 | — | 1 | — | — | — | — | 1 | — | — | 3 | — | — | — | 1 | — | — | 1 | — | 1 | — | 1 | — | — |
| 8 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

Table 2. Personal Age Composition. Explanation: See p. 139 (2)

(Ⅰ) Herring

| Person \ Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| A | — | — | 3 | 20 | 19 | 2 | — | — |
| B | — | — | 3 | 19 | 18 | 4 | — | — |
| C | — | — | 4 | 35 | 5 | — | — | — |
| D | — | — | 2 | 22 | 20 | — | — | — |
| E | — | — | 4 | 25 | 12 | 3 | — | — |
| F | — | — | 2 | 19 | 21 | 2 | — | — |
| G | — | — | 3 | 17 | 23 | 1 | — | — |
| H | — | — | 4 | 23 | 13 | 3 | 1 | — |
| I | — | — | 4 | 22 | 16 | 2 | — | — |
| J | — | — | 3 | 19 | 20 | 2 | — | — |
| K | — | — | — | 33 | 11 | — | — | — |
| L | — | 1 | 1 | 10 | 16 | 7 | 6 | 3 |
| M | — | — | 1 | 14 | 21 | 5 | 2 | 1 |
| N | — | — | 3 | 24 | 16 | 1 | — | — |
| O | — | — | — | 28 | 15 | — | 1 | — |
| P | — | — | 2 | 17 | 21 | 3 | 1 | — |
| Q | — | — | 4 | 22 | 14 | 3 | 1 | — |
| R | — | — | 2 | 21 | 18 | 1 | 2 | — |
| S | — | — | 4 | 21 | 17 | 2 | — | — |

(Ⅱ) Sauro

| Person \ Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| A | — | — | 4 | 23 | 14 | 1 | — | — |
| B | — | — | 5 | 26 | 11 | — | — | — |
| C | — | — | 14 | 15 | 11 | 2 | — | — |
| D | — | — | 8 | 28 | 6 | — | — | — |
| E | — | 1 | 10 | 24 | 7 | — | — | — |
| F | — | — | 3 | 23 | 15 | 1 | — | — |
| G | — | — | 8 | 20 | 12 | 2 | — | — |
| H | — | 1 | 12 | 17 | 7 | 3 | 2 | — |
| I | — | — | 3 | 20 | 19 | — | — | — |
| J | — | 1 | 16 | 25 | — | — | — | — |
| K | — | — | 21 | 21 | — | — | — | — |
| L | — | 1 | 4 | 12 | 18 | 5 | 1 | 1 |
| M | — | — | 6 | 22 | 14 | — | — | — |
| N | — | 4 | 16 | 15 | 6 | — | 1 | — |
| O | — | — | 1 | 12 | 20 | 9 | — | — |
| P | — | — | — | 2 | 12 | 20 | 8 | — |
| Q | 1 | 18 | 16 | 6 | 1 | — | — | — |
| R | — | 11 | 12 | 13 | 3 | 1 | 2 | — |
| S | — | — | 9 | 15 | 13 | 2 | 3 | — |

(Ⅲ) Common Goby

| Person \ Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| A | — | 12 | 18 | 8 | 3 | — | — |
| B | — | — | 16 | 24 | 1 | — | — |
| C | — | 20 | 20 | 1 | — | — | — |
| D | — | 2 | 14 | 24 | 1 | — | — |
| E | — | 4 | 26 | 10 | 1 | — | — |
| F | — | — | 7 | 19 | 11 | 4 | — |
| G | — | — | 5 | 18 | 13 | 4 | 1 |
| H | — | — | 15 | 22 | 3 | 1 | — |
| I | — | — | 17 | 17 | 6 | 1 | — |
| J | — | 7 | 25 | 8 | 1 | — | — |
| K | — | — | 7 | 28 | 6 | — | — |
| L | — | 3 | 12 | 14 | 9 | 3 | — |
| M | 5 | 19 | 14 | 3 | — | — | — |
| N | — | 9 | 19 | 11 | 2 | — | — |
| O | — | 1 | 14 | 19 | 7 | — | — |
| P | — | 2 | 9 | 21 | 9 | — | — |
| Q | — | 5 | 18 | 17 | 1 | — | — |
| R | — | 2 | 17 | 15 | 6 | 1 | — |
| S | — | — | 6 | 24 | 8 | 3 | — |

(Ⅳ) Sole (Otolith)

| Person \ Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| A | — | 1 | 19 | 16 | 7 | — | — |
| B | — | — | 2 | 14 | 18 | 8 | 1 |
| C | — | 4 | 27 | 10 | 2 | — | — |
| D | — | 5 | 30 | 8 | — | — | — |
| E | — | 2 | 19 | 18 | 4 | — | — |
| F | — | 2 | 14 | 24 | 3 | — | — |
| G | — | — | 4 | 15 | 17 | 6 | 1 |
| H | — | 7 | 24 | 10 | 2 | — | — |
| I | — | 6 | 22 | 13 | 2 | — | — |
| J | 3 | 17 | 18 | 4 | 1 | — | — |
| K | — | 5 | 37 | 1 | — | — | — |
| L | — | — | 7 | 13 | 12 | 8 | 3 |
| M | — | 5 | 7 | 18 | 9 | 4 | — |
| N | — | 12 | 24 | 5 | 2 | — | — |
| O | — | 1 | 6 | 20 | 9 | 6 | 1 |
| P | — | — | 4 | 12 | 20 | 7 | — |
| Q | — | — | 12 | 22 | 9 | — | — |
| R | — | 3 | 10 | 12 | 11 | 4 | 3 |
| S | — | — | 6 | 20 | 12 | 4 | 1 |

(Ⅴ) Yellowfin Tuna

| Person \ Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| A | — | — | 1 | 9 | 16 | 15 | 6 | 3 | — | — |
| B | — | — | — | 5 | 19 | 16 | 8 | 2 | — | — |
| C | — | — | 3 | 21 | 24 | 2 | — | — | — | — |
| D | — | — | — | 19 | 15 | 14 | 2 | — | — | — |
| E | — | — | 4 | 16 | 17 | 12 | 1 | — | — | — |
| F | — | — | — | 6 | 13 | 20 | 8 | 2 | 1 | — |
| G | — | — | 4 | 12 | 20 | 7 | 4 | 2 | — | 1 |
| H | — | — | — | 11 | 17 | 15 | 5 | 2 | — | — |
| I | — | — | 5 | 19 | 19 | 7 | — | — | — | — |
| J | — | — | 2 | 10 | 26 | 9 | 3 | — | — | — |
| K | — | — | 2 | 26 | 20 | 2 | — | — | — | — |
| L | — | — | 1 | 8 | 17 | 18 | 4 | 1 | 1 | — |
| M | 1 | 2 | 23 | 16 | 7 | 1 | — | — | — | — |
| N | — | 8 | 16 | 18 | 5 | 1 | — | — | 2 | — |
| O | — | — | 14 | 18 | 13 | 2 | 2 | 1 | — | — |
| P | — | — | — | 2 | 13 | 24 | 9 | 2 | — | — |
| Q | — | 3 | 13 | 14 | 9 | 9 | 2 | — | — | — |
| R | — | — | 2 | 9 | 19 | 10 | 6 | 1 | 2 | 1 |
| S | — | — | — | 5 | 13 | 16 | 9 | 4 | 3 | — |

(Ⅵ) Crucian carp

| Person \ Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| A | — | 1 | 8 | 19 | 16 | 2 | 1 | — |
| B | — | — | 3 | 25 | 19 | — | — | — |
| C | — | — | 2 | 21 | 18 | 4 | 2 | — |
| D | — | 1 | 13 | 20 | 13 | — | — | — |
| E | 3 | 10 | 21 | 10 | 3 | — | — | — |
| F | — | 1 | 8 | 9 | 20 | 7 | 2 | — |
| G | — | 3 | 10 | 16 | 11 | 4 | 3 | — |
| H | — | 10 | 8 | 17 | 11 | 1 | — | — |
| I | — | 2 | 12 | 20 | 9 | 4 | — | — |
| J | 15 | 3 | 7 | 12 | 10 | — | — | — |
| K | — | 1 | 5 | 23 | 17 | 1 | — | — |
| L | 14 | 5 | 4 | 11 | 7 | 6 | — | — |
| M | — | 17 | 12 | 11 | 4 | 3 | — | — |
| N | 19 | 7 | 8 | 6 | 5 | 2 | — | — |
| O | — | 1 | 3 | 9 | 15 | 11 | 7 | 1 |
| P | — | 3 | 18 | 20 | 5 | 1 | — | — |
| Q | 1 | 1 | 13 | 20 | 7 | 4 | 1 | — |
| R | 7 | 6 | 10 | 9 | 8 | 3 | 3 | 1 |
| S | — | — | 3 | 6 | 13 | 18 | 7 | — |

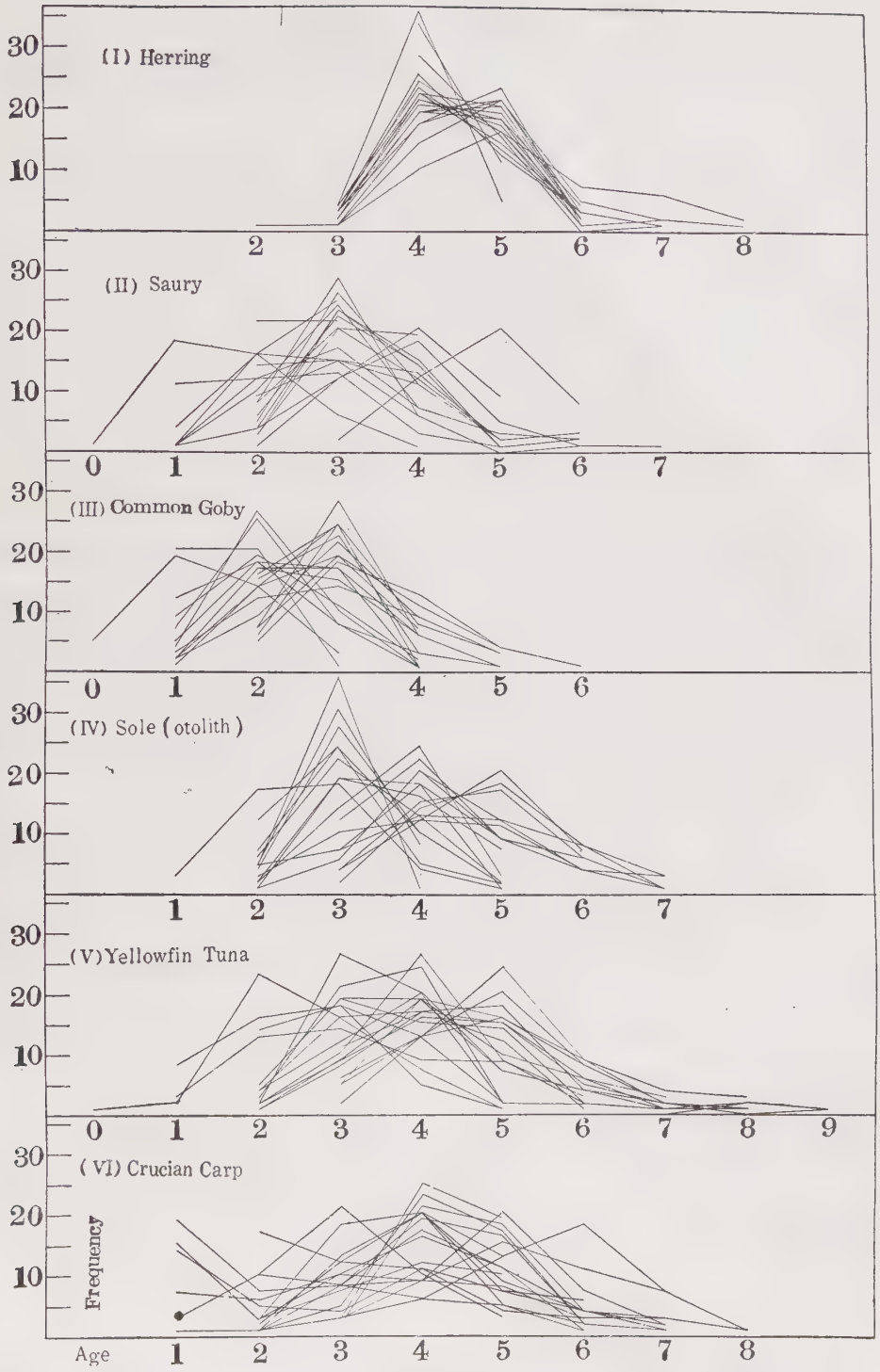



Fig. 1. Personal Age Composition. Explanation: See p. 139 (2)

Table 3. Explanation:— See p. 139 (3)

| | Herring | Saury | Common Goby | Sole(Otolith) | Yellowfin Tuna | Crucian carp |
|---|---|---|---|---|---|---|
| 4 | — | — | — | — | — | 1 |
| 5 | — | — | 1 | 4 | 2 | 5 |
| 6 | — | 4 | 1 | 3 | 13 | 11 |
| 7 | 1 | 4 | 6 | 8 | 13 | 9 |
| 8 | 1 | 7 | 7 | 8 | 8 | 11 |
| 9 | 3 | 5 | 9 | 8 | 6 | 4 |
| 10 | 3 | 8 | 9 | 4 | 3 | 3 |
| 11 | 2 | 9 | 3 | 2 | 4 | 2 |
| 12 | 6 | 2 | 2 | 3 | 1 | 1 |
| 13 | 6 | 3 | 1 | 3 | — | — |
| 14 | 8 | — | 1 | — | — | — |
| 15 | 3 | — | 1 | — | — | — |
| 16 | 3 | — | — | — | — | — |
| 17 | 4 | — | — | — | — | — |
| 18 | 3 | — | — | — | — | — |
| 19 | 1 | — | — | — | — | — |
| | 44 | 42 | 41 | 43 | 50 | 47 |

(4) Finally, a trial was made to discover the personal tendency in age determination. Because we are not aware of what value of age is true for a certain sample, the average age value read by nineteen persons for each sample ($\overline{X_j}$) is obtained as a sort of standard which might be regarded as being near the right value. Moreover, the difference of the average value from each read value by person $i$ about a sample numbered $j$, ($X_{ij}-\overline{X_j}$) is regarded as a deviation from the average. Then, the personal tendency of deviation for a certain fish kind $I$ is

$$d_{iI}=\frac{1}{N}\sum_{j=1}^{N}(X_{ij}-\overline{X_j}) \quad \text{(where } N \text{ is number of samples of fish species } I\text{)}.$$

These values ($d_{iI}$) are lined up in the upper line of Table 4. So, if the value $d_{iI}$ is less than 0, it means the person $i$ has a tendency to read the age less than the average person; on the contrary, if $d_{iI}$ is more than 0, he has the tendency to read it as more than the average, and the more the absolute value of $d_{iI}$ the greater is his tendency of deviation.

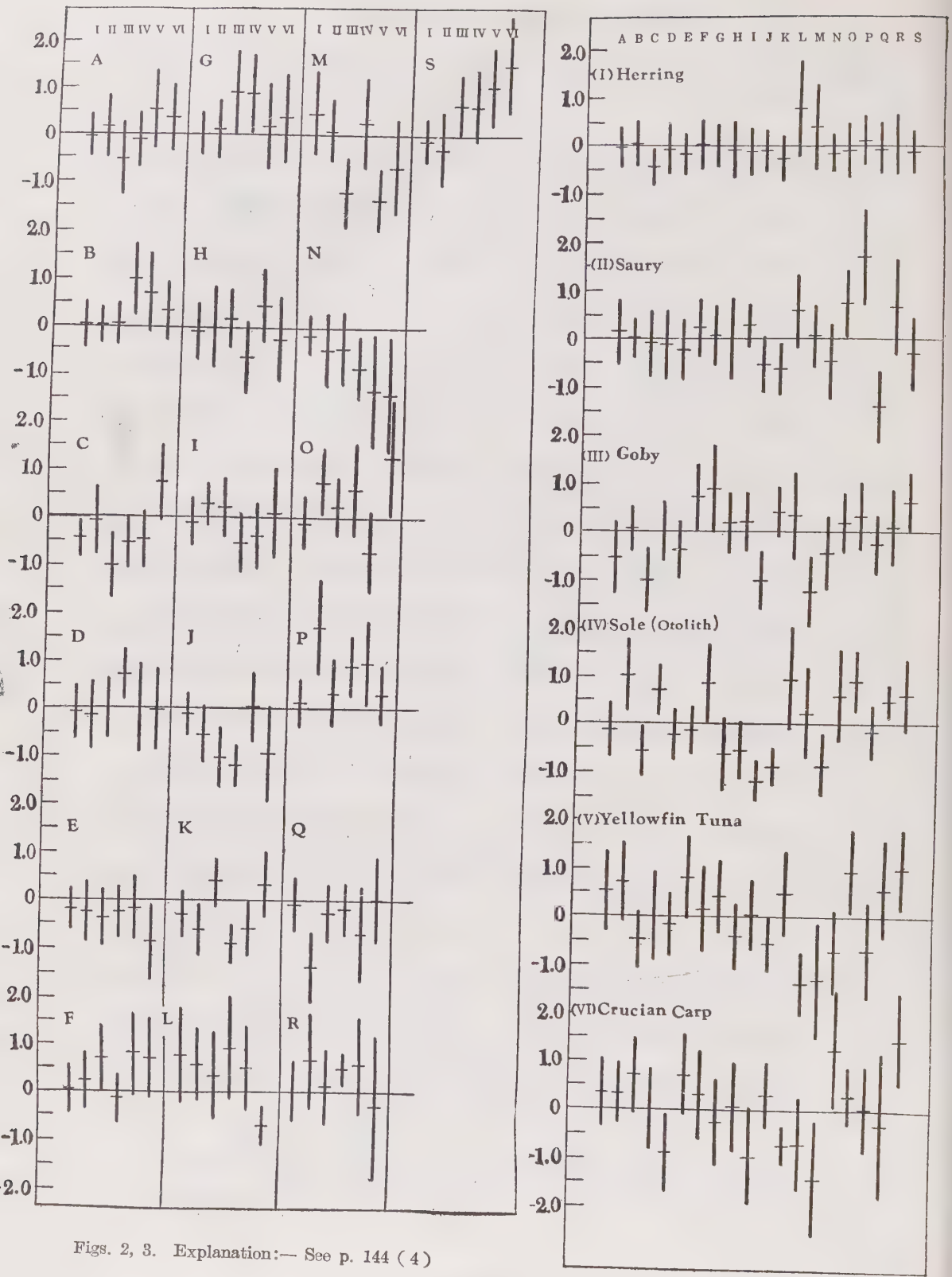
However, the absolute value of $d_{iI}$ is reduced if he read some samples as greater than average and others as less. So, to be a measure of the size of the deviation, a sort of standard deviation $D_{iI}$ is obtained by the following formula, and attatched in the bracket to $d_{iI}$ in the upper line of Table 4.

$$D_{iI}=\frac{1}{\sqrt{N}}\left[\sum_{j=1}^{N}(X_{ij}-\overline{X_j})^2-\frac{1}{N}\{X_{ij}-\overline{X_j})\}^2\right]^{\frac{1}{2}}$$

Both $d_{iI}$ (the center) and $D_{iI}$ (the bar) are expressed in graphs of Fig. 2 and Fig. 3, the former being classified by observers named by letters and the latter by fish species.

Table 4. Explanation:— See p. 144 ( 4 )

| Fish species / Person | Herring | Saury | Common Goby | Sole (Otolith) | Yellowfin Tuna | Cu cian carp | $P_i$ $P_i'$ ($P_i''$) |
|---|---|---|---|---|---|---|---|
| A | −0.03(0.44) | 0.18(0.69) | −0.52(0.78) | −0.11(0.59) | 0.53(0.86) | 0.33(0.71) | 0.68 |
| | 0.36(0.34) | 0.58(0.54) | 0.83(0.68) | 0.53(0.49) | 1.01(0.84) | 0.66(0.94) | 0.66(0.64) |
| B | 0.04(0.49) | 0.04(0.43) | 0.03(0.46) | 1.03 0.77) | 0.69(0.83) | 0.33(0.63) | 0.60 |
| | 0.38(0.24) | 0.32(0.42) | 0.40(0.46) | 0.79(0.97) | 0.97(0.83) | 0.65(0.58) | 0.59(0.58) |
| C | 0.46(0.41) | 0.08(0.70) | −1.01(0.67) | −0.55(0.52) | 0.47(0.60) | 0.70(0.80) | 0.62 |
| | 0.52(0.58) | 0.58(0.58) | 1.05(1.43) | 0.61(0.33) | 0.84(1.01) | 0.88(0.60) | 0.75(0.76) |
| D | −0.08(0.55) | −0.11(0.72) | 0.01(0.62) | 0.71(0.51) | 0.01(0.95) | 0.02(0.86) | 0.70 |
| | 0.44(0.42) | 0.47(0.54) | 0.49(0.44) | 0.72(0.67) | 0.83(0.73) | 0.71(0.94) | 0.61(0.62) |
| E | −0.17(0.40) | −0.22(0.64) | −0.38(0.61) | −0.23 0.52) | −0.17(0.68) | −0.82(0.82) | 0.61 |
| | 0.38(0.34) | 0.49(0.54) | 0.60(0.62) | 0.44(0.49) | 0.58(0.61) | 1.07(0.96) | 0.59(0.59) |
| F | 0.04(0.50) | 0.23(0.59) | 0.72(0.71) | −0.13(0.49) | 0.83(0.88) | 0.70(0.82) | 0.67 |
| | 0.44(0.40) | 0.48(0.38) | 0.84(0.82) | 0.39(0.41) | 1.05(1.09) | 0.88(1.28) | 0.68(0.73) |
| G | 0.01(0.44) | 0.09(0.63) | 0.89(0.90) | 0.87(0.85) | 0.15(0.90) | 0.31(0.92) | 0.81 |
| | 0.36(0.34) | 0.48(0.58) | 1.03(1.04) | 0.95(0.77) | 0.72(0.49) | 0.91(0.94) | 0.74(0.69) |
| H | −0.08(0.59) | 0.01(0.85) | 0.19(0.62) | −0.62(0.78) | 0.43(0.76) | −0.24(0.89) | 0.75 |
| | 0.48(0.32) | 0.63(0.62) | 0.51(0.42) | 0.74(0.33) | 0.80(0.75) | 0.80(0.92) | 0.66(0.56) |
| I | −0.12(0.50) | 0.28(0.44) | 0.21(0.75) | −0.53(0.61) | −0.41(0.69) | 0.08(0.95) | 0.66 |
| | 0.41(0.58) | 0.45(0.36) | 0.66(0.68) | 0.59(0.47) | 0.71(0.77) | 0.75(0.56) | 0.60(0.57) |
| J | 0.09(0.44) | 0.53(0.59) | −0.50(0.62) | −1.18(0.43) | 0.05(0.73) | −0.96(1.06) | 0.65 |
| | 0.36(0.24) | 0.64(0.62) | 0.65(0.86) | 1.19(0.75) | 0.61(0.45) | 1.17(1.18) | 0.77(0.68) |
| K | −0.24(0.49) | 0.61(0.54) | 0.41(0.52) | −0.88(0.41) | −0.53(0.57) | 0.31(0.65) | 0.53 |
| | 0.43(0.43) | 0.66(0.72) | 0.58(0.66) | 0.85(0.95) | 0.66(0.59) | 0.64 0.78) | 0.64(0.69) |
| L | 0.81(1.00) | 0.57(0.77) | 0.36(0.91) | 0.91(1.09) | 0.49(0.90) | −0.73(0.41) | 0.85 |
| | 1.04(1.02) | 0.86(1.08) | 0.81(0.96) | 1.07(0.39) | 0.75(0.81) | 1.23(1.08) | 0.96(0.89) |
| M | 0.42(0.89) | 0.09(0.65) | −1.21(0.73) | 0.22(0.94) | −1.39(0.64) | −0.71(0.95) | 0.80 |
| | 0.66(0.40) | 0.47(0.46) | 1.24(1.34) | 0.79(0.77) | 1.43(1.43) | 0.99(1.12) | 0.93(0.92) |
| N | −0.15(0.39) | −0.46(0.73) | −0.42(0.78) | −0.85(0.64) | −1.27(1.20) | −1.43(1.19) | 0.82 |
| | 0.36(0.34) | 0.70(0.78) | 0.75(0.58) | 0.92(0.69) | 1.54(1.33) | 1.55(1.22) | 0.97(0.82) |
| O | −0.08(0.56) | 0.78(0.75) | 0.31(0.64) | 0.59(0.94) | −0 71(0.87) | 1.27(1.20) | 0.83 |
| | 0.43(0.36) | 0.85(0.58) | 0.53(0.56) | 0.74(0.47) | 0.93(0.89) | 1.56(0.96) | 0.84(0.64) |
| P | 0.15(0.51) | 1.71(0.98) | 0 33(0.71) | 0.91(0.64) | 0.95(0.89) | 0.30(0.60) | 0.72 |
| | 0.40(0.34) | 1.67(1.08) | 0.63(0.44) | 1.00(1.25) | 1.16(1.67) | 0.61(0.46) | 0.91(0.87) |
| Q | −0.05(0.51) | −1 39(0.74) | −0.23(0.61) | 0.15(0.56) | −0.69(1.03) | 0.06(0.91) | 0.73 |
| | 0.45(0.54) | 1.42(1.16) | 0.53(0.46) | 0.47(0.27) | 1.11(1.73) | 0.75(0.76) | 0.79(0.82) |
| R | 0.06(0.62) | 0.66(1.00) | 0.11(0.79) | 0.50(0.34 | 0.53(1.03) | −0.28(1.50) | 0.88 |
| | 0.46(0.62) | 1.10(0.82) | 0.65(0.66) | 0.93(1.15) | 0.87(0 81) | 1.11(1.38) | 0.85(0.91) |
| S | −1.00(0.44) | 0.30(0.76) | 0.62(0.61) | 0.61(0.77) | 1.09(0.84) | 1.48(0.97) | 0.73 |
| | 0.38(0.38) | 0.62(0.96) | 0.70(0.86) | 0.84(0.57) | 1.20(0.87) | 1.63(1.64) | 0.89(0.88) |
| $A_i$ | 0.54 | 0.69 | 0.69 | 0.65 | 0.83 | 0.89 | |
| $A_i'(A_i'')$ | 0.46(0.43) | 0.71(0.67) | 0.71(0.73) | 0.77(0.73) | 0.91(0.92) | 0.98(0.96) | |




Figs. 2, 3. Explanation:— See p. 144 ( 4 )

To see the extent of personal deviation from the average reading throughout six species, which would be considered to be a measure of qualification to be a normal age reader, the average of $D_{iI}$ throughout six species $P_i=\frac{1}{6}\sum_{I=1}^{6}D_{iI}$ was obtained as shown in Table 4.

Instead of $D_{iI}$, another value of the amount of personal deviation from the average, having nearly the same meaning as $D_{iI}$, the summation of the absolute value of each deviation, which can be expressed as $D_i'=\frac{1}{N}\sum_{J=1}^{N}|X_{iJ}-\overline{X}_J|$ was obtained, and is shown in the lower lines in Table 4.

Since the value of $d$ or $D$ is too large, frequently exceeding 1, as seen from Table 4, at first the value was thought to be influenced by the number of samples, so two values having different $N$ were compared. Thus, $D''$ is obtained for 40 samples and $D'$ for 10 samples, both according to the above formula of $D'$, and the samples were picked up quite random from all the samples here examined. In Table 4, in each lower line $D'$ and $D''$ are shown, the latter being in brackets. In the same way, $P'$ and $P''$ are obtained as the personal average throughout the six species, and shown in the same table. However, we cannot see a marked difference between $P'$ and $P''$, some being slightly more and others less. Though we do not think the difference between the numbers, 10 and 40, is sufficient to present the difference, within this extent, the extent of personal deviation from the average cannot be changed according to the number of the samples, and it must be caused by the individual nature of the observer.

4. *Degree of Difficulty of age reading* As already shown in Fig. 1, Table 3 and others, generally the personal difference is less in the case of the herring than in the others. Therefore, the authors wished to obtain a measure of the degree of difficulty of age reading about certain fish species. As shown in Table 4, the three summations of $D$, $D'$ and $D''$ for each fish kind are obtained. They are

$$A_I=\frac{1}{19}\sum_{i=A}^{S}D_{iI}\ ,\qquad A_I'=\frac{1}{19}\sum_{i=A}^{S}D'_{iI}\ ,\qquad A_I''=\frac{1}{19}\sum_{i=A}^{S}D''_{iI}\ .$$

Table 4 showns that $A$, $A'$ and $A''$ are in order of I, II, III, IV, V, and VI, i. e. the herring offers least difficult and the Crucian carp, the most.

5. *Conclusion* Being the teachers of these nineteen students who finished the course of Age Determination, we do not want to think that this large deviation in age reading is caused by the insufficient training in this sort of technique. Recently Fitch (1951) reported in otolith reading of the Pacific Mackerel that two

well trained biologists, Mr. D. H. Fry and himself, read the same sample of about 2,000, and found that the age compositions obtained by the two of them did not show remarkable differences from each other. Ikeda and Saishu (1952) reported the results of scale reading of numerous samples of coakers by three biologists, in which there were more cases of coincidental reading than in our case. Comparing our results with these above-mentioned works, we feel that there may be a great chance that two or three observers may have the tendency to read the scales close together, and it happens in these cases, as well as with some two or three of our observers among nineteen. The results here obtained and analysed make us quite pessimistic to require high objectiveness and accuracy in age determination, which supplies quite important basic data for the knowledge of growth, age composition of population and other subjects in fisheries biology, although we know this is the best at the present stage of development of science.

*References*

FITCH, J. E. (1951) Age composition of the Southern California catch of Pacific Mackerel. Fish Bulletin 83, Department of Fish and Game, California.

IKEDA, I. and SAISHU, (1952) Age determination (Japanese), Sokouo Shigenchosa Kenkyurenraku. No. 12, July 1952, pp. 2–10.

# CATCHES OF A JAPANESE TRAWLER IN SAURASHTRA WATERS

K. R. Srivatsa

Directorate of Marine Products, Government of Saurashtra, Gamnagar, India.

1. *Introduction.* The Taiyo Maru No. 17, one of the finest steel deep sea trawlers of the Taiyo Fishing Co. of Japan is presently operating in Saurashtra and Bombay waters. The vessel, which started fishing from 28th November, 1951, is a 270-ton, 550 BHP diesel trawler with a crew of 23 under an experienced captain, T. Emata. The present review is a short note on the catches of this trawler which has made a world record in total catches per day.

During the financial year 1921/22 from May to February, the steam trawler "WILLIAM CARRICK" operated in the Bombay, Kathiawad and Sind waters. Although the trawling operations financially resulted in a colossal failure, yet valuable fishing grounds of Kathiawad were located, especially beyond the 15 fathom line. The productivity of these waters and the catches and relativity of the catches to the gears and methods employed have been described by A. E. Hefford.

Yet the production of fish in the Indian waters by otter or beam trawling, correlated with the capital, sales, manpower, gear, tonnage of the boat, absense of vessel from port, period of trawling and hours and number of hauls is very poor according to normal western or Japanese standards. H. T. Storley's comparison of "Golden Grown" & "William Carrick" with the European trawlers of 1913 is misleading, as the commercial importance of the Indian catches and the European catches were poles apart. While the Iceland and Irish Trawlers went for selective trawling depending upon the valuable Pleuronectidae, Gadidae, Sparidae and Percidae, the majority for the Indian catches were uneconomical sharks, dogfishes, rays or *Trichiurus*.

It is not intended here to discuss the demerits of the Indian trawling operations although the operations of S. T. Premier (1900), S. B. Margharita (1907-08), St. Madras (23), S. T. Nautiles (1924), S. T. Golden Crown (1908-11), S. T. William Carrick (1921-22), S. T. Goschen (27-28), S. T. Meena (1948), Sagariga, (1949-51), Jyoti Tapase (1950) ended in failure. The particulars about the fishing grounds exploited and the types of fish caught, identified as to species, are available only in the

case of S. T. William Carrick and S. T. Goschen, although the particulars of the latter are incomplete.

The waters of Saurashtra (Kathiawad) were trawled during 1948-49 and during 1950 and 1951 also periodically by S. T. Meena and the Danish Cutters Ashok and Pratap. Although the results of the cutters operations have become more encouraging, the particulars of the piscine fauna of the catches, identified by the survey officers of the Government of India, have not yet been published.

From November, 1950 to February, 1951, 4 Japanese technicians leni by the Taiyo Fishing Co. of Japan operated with two local vessels Jyothi and Tapase belonging to Messrs Kenico Ltd. of Saurashtra. The Nisso Sokobikiami was operated at 10 to 15 fathoms off Veraval, Mangrol, Dui and Porbunder, and 67 tons of fish were caught in 61 fishing days, averaging 22 cwts per day or 7 cwts per haul.

An analysis of the catches was made by the author at Veraval and Porbunder ports, and although the identification of the catches up to the species was then impossible, it was found that the majority of the catches were *Aeotobatis*, *Myliobatis*, *Trygon*, *Carcharius*, *Zygaena*, *Arius*, *Rhyncobatus*, *Serranus*, *Seiaena*, *Lutjanus*, *Pristipoma*, *Muraenosox*, *Stromateus*, *Therapon*, *Umbrina*, *Clupea Ilisha*, *Drepane*, *Polynemus*, *Caranx*, *Chorinemus* and *Crustaceans*, in the order of abundance.

During the year 1951/52 the fisheries department of Saurashtra was engaged upon the proper identification of the fish catches landed by the coastal fisherman at Nawabunder, Porbunder, Sikka and Jamnagar for communication to the Indo Pacific Fisheries Council. The State of Saurashtra invited the 270-ton Japanese Trawler, 'Taiyo Maru,' to fish in their deep seas and the Government of India permitted the vessel to fish in Bombay and Saurashtra waters for 8 months, from 25th November, 1951 to 31st July 1952.

An attempt was made to analyse the Japanese catches in Saurashtra waters and record the analysis as the piscine fauna of the deeper waters of the State of Saurashtra. There were many facilities for conducting the identification work on the trawler. The author took the opportunity of identifying the catches when he was on board the vessel on two occasions for 2 full weeks in January and May 1952, and at Veraval during January 1952 and at Bombay during April, 1952.

During the period from November, 1951 to June 1952 the Japanese captain, Mr. Emata and the director, Mr. Ueda also assisted the author in securing particulars of fish not previously identified properly.

2. *Operations of Taiyo Maru.* From the end of November, 1951 to 30th

June, 1952 the Taiyo Maru operated 815 hauls in 132 fishing days, remaining 170 days out of port, and catching 760 tons of fish. The relative statistics on absence from port and fishing, when compared to Japanese and Europeon operations, creates a world Record. The Taiyo Maru caught at an average of 18.0 cwts. of fish per haul, 115 cwts per fishing day and 89.4 cwts. per day out of port.

Except for a period of 11 days from 16-5-52 to 26-5-52 and for a brief fishery of 3 days in Bombay waters from 3-3-52 to 5-3-52, the trawler operated mainly in Saurashtra waters. An analysis of the sections and durations of fishing is given below with the catches thereof:—

Table I.

| Sr. No. | Section No. | Total No. of hauls made during the period. | Total tonnage caught in this section. | Average catch per haul. |
|---|---|---|---|---|
| 1. | 22 | 86 | 138 tons | 1.6 tons |
| 2. | 15 | 207 | 234 tons | 1.13 tons |
| 3. | 23 | 110 | 107.5 tons | 0.93 tons |
| 4. | 34 | 70 | 81.7 tons | 1.17 tons |
| 5. | 42 | 55 | 44.2 tons | 0.8 tons |
| 6. | 41 | 68 | 34.0 tons | 0.5 tons |
| | Total: | 598. | 639.4 tons. | 1.08 tons. |

From this it is found that the best sections or fishing grounds are off Dwarka and Mangrol, Veraval.

In correlating catches with depth, it was found that $15^1/_2$ to 18 fathoms with mud was the most productive ground. Moreover the deep water temperature was found to have a definite determining factor on the movement of the Sciaenoids, Polynemus, Stromateus, Pristipoma and crustaceans. The maximum catches obtained in Section 15 off Dwarka was at temp 23° to 25° C. The planktons collected from these sections are being analysed by the Fisheries Department of Saurashtra; in sections 15, 22 and 23 they were abundant and variegated-phytoplanktons preponderating.

The trawler let go the rope at Section 41 off Mangrol, but soon found that the grounds were mostly the habitat of elasmobranchs, especially Rajidae. After a month they struck good grounds on Sections 15, 23, 22 and 40 and therefore remained there, except for experimentations and exploitation of new grounds.

The monthwise catches and particulars are given in Table II.

An analysis of the Japanese trawling in Saurashtra waters reveals a few points to be noted in conducting trawling in Indian Waters.

They are (1) Trawling is a technical operation and is very closely dependent

Table II.

| No. | Month & No. of voyages. | No. of days. | Fishing hauls. | Total catches in tons | Important and dominant catches as per % of composition in order of catches. |
|---|---|---|---|---|---|
| 1. | Nov. 26th to Dec. 20th (3 voyages) | 25 | 123 | 126.5 | *Pristipoma*, Sharks, Roys, *Sciaena*, *Polynemus indicus*, *Mureanosox*, Umbrina *Argyrops*, *Sciaenoides*, Catfishes & Pomfrets. |
| 2. | Jan. 2nd to Jan. 30th (2 voyages) | 19 | 117 | 124.8 | *Polynemus indicus*, *Pristipoma*, Rays, Sharks, *Sciaena*, *Umbrina*, Catfishes, *Sciaenoides*. |
| 3. | Feb. 1st to 28th (2") | 17 | 91 | 86.3 | *Polynemus indicus*, *Pristipoma*, Rays, *Sciaenoides*, Catfishes, Sharks, *Umbrina*, *Sciaena*, *Harpodon*, *Mureanosox*. |
| 4. | March 3rd to 29th (2") | 24 | 142 | 87.6 | *Sciaena*, *Polynemus indicus*, *Pristipoma*, *Umbrina*, Catfishes, Sharks, Rays, *Sciaenoides*, *Mureanosox*, Pomfrets. |
| 5. | April 2nd to 30th (2") | 20 | 105 | 123.1 | *Pristipoma*, *Sciaena*, Sharks, *Mureanosox*, *Umbrina*, Catfishes, Scomber, *Polynemus indicus*, *Sciaenoides*, *P. tetradactylus*, Pomfrets. |
| 6. | April 30th to May 9th | 10 | 53 | 57.0 | *Pristipoma*, *Sceiaena*, Sharks, *Umbrina*, Catfishes, Scomber, *Lutjanus*, *Harpodon*, |
| 7. | May 28th to June 26th | 15 | 119 | 110.0 | Pomfrets, *Sciaena*, *Umbrina*, *Mureanosox*, Sharks, *Pristipoma*, Rays, Pomfrets, *Caranx*. |

upon the oceanography of the location and the trawl net:— (a) The Japanese have a specialised trawl net and they vary the position of the net accorping to the depth of the sea and the speed of the current; (b) They study the productivity of the sea by ascertaining the optimum conditions of temperature and depth for particular shoals of fishes; (c) They study also the planktons and movement of the shoals by the echo sounder. (2) The revolutions per minutes of the engine, speed of the boat etc. are directly proportional to the resistance offered to the net by currents and depth. (3) The semi-temperate waters of Saurashtra are the natural habitat of shoaling and the majority of deep sea fish like the Sciaenids, *Polynemus*, *Pristipoma*, *Stromateus* etc., and as trawling always depends upon shoaling under water fish, quantity of the group is the denominator for trawling. In Madras and other tropical areas the quantity of the particular group is less and the diversity of varieties is greater.

These points are discussed in another publication about Japanese trawling by the author.

3. *Analysis of the Catches.* The best catches were obtained from January 2nd to 8th at 7-23 tons per fishing day with a majority of *Polynemus indicus*, *Pristipoma argenteum*, *Sciaena sina*, *Umbrina* and *Lutjanus argentimaculatus*; from January 16 to 30th at 7.4 tons per day with a majority of *Polynemus indicus*, *Pristipoma argenteum*, *Sciaena sina*, *Caranx rottalleri* and *Lutjanus*; from February 1st to 8th a record catch of *Polynemus* was obtained. April 2nd to 10th, when about 20 tons of *Sciaena sina* and 20 tons of *Pristipoma* and 3 tons of *Polynemus* were

obtained. April 30th to May 9th with about 20 tons of *Sciaena sina*, 5 tons of *Pristipoma argenteum* and $4^1/_2$ tons of *Umbrina*; June 16th to 26th, when 36 tons of *Sciaena sina*, 18 tons of Elasmobranchs and $5^1/_2$ tons of *Pristipoma* were obtained.

The chart below shows the various types of fish and the quantity caught:—

Table III.

| Sr. No. | Name of fish | Total catches for the period. |
|---|---|---|
| 1. | *Pristipoma argenteum.* | 147.7 |
| 2. | *Sciaena sina.* | 120.3 |
| 3. | *Polynemus indicus.* | 103.7 |
| 4. | *Carcharius.* | 61.8 |
| 5. | *Aeotobatis trygon & Myleobatis.* | 50.0 |
| 6. | *Umbrina.* | 49.6 |
| 7. | *Mureanosox.* | 47.0 |
| 8. | *Arius* and other catfish. | 41.0 |
| 9. | Sciaenoides. | 26.0 |
| 10. | *Harpodon.* | 12.0 |
| 11. | *Argerops* or *Pagrus.* | 11.0 |
| 12. | Pomfrets. | 10.5 |
| 13. | *Lutjanus argentimaculatus.* | 9.3 |
| 14. | Scomber. | 7.7 |
| 15. | *Ceupea illisha.* | 6.8 |
| 16. | *Polynemus tetradactylus.* | 6.0 |
| 17. | *Caranx Rotleeri.* | 5.3 |
| 18. | *Trichiurus.* | 4.0 |
| 19. | *Chorinemous.* | 2.2 |
| 20. | *Cybium sp.* | 2.0 |
| 21. | *Lutjanus niger.* | 1.5 |
| 22. | *Chirocentrus.* | 0.6 |
| 23. | *Drepane.* | 0.3 |
| 24. | *Lobsters, prawns, etc.* | 0.3 |

Out of the catches, *Pristipoma argenteum*, *Sciaena Sina* and *Polynemus indicus* formed the maximum amount of catches in the order as above. They were caught in various sections but were abundant in sections 15, 22, 23, 34, 41 & 42. The Table IV shows the abundance of these fish in the various sections trawled.

The Japanese also caught about 17.5 tons of *Scomber microlepidotus* and about $1^1/_2$ tons of *Lutjanus niger*. These fishes are identified later.

I have to thank Shri M. Thirumoolanathan of the Directorate of Marine Products for checking this report and comparing the species with Max Waber and De Beaufort's "The Fishes of the Indo Australian Archipelago." He also helped the author in the compilation of the statistical data.

The Japanese Captain Emata and Director Ueda helped me a great deal in compiling this note. The statistical data is from their reports regularly sent to the Government of India and the State of Saurashtra. The great emphasizing fact is that this medium trawler has exploded the myth "that commercial trawling is not possible in Indian waters." The Taiyo Fishing Co. has succeeded where others have failed with reference to off-shore trawling in India.

Table IV. Major catches in the important netting sections.

| Sr. No. | Name of fish | Catches in tons in all the operation sections | | | | | | Total catches of the species in these sections. |
|---|---|---|---|---|---|---|---|---|
| | | No. 15 | No. 22 | No. 23 | No. 34 | No. 41 | No. 42 | |
| 1. | *Pristipoma* sp. | 16.2 | 68.5 | 27.5 | 7.8 | 1.5 | 2.7 | 123.5 |
| 2. | *Sciaena* sp. | 13.6 | 25.0 | 17.4 | 7.8 | 5.0 | 18.7 | 87.5 |
| 3. | *Polynemus indicus.* | 9.8 | 23.5 | 21.6 | 0.3 | 0.7 | 4.5 | 60.4 |
| 4. | Sharks. | 4.5 | 11.5 | 5. | 2.5 | 1.0 | 2.5 | 27.0 |
| 5. | Rays. | 1.5 | 7.2 | 5.0 | 6.8 | 3.0 | 7.0 | 30.5 |
| 6. | *Umbrina.* | 4.7 | 10.3 | 4.5 | 3.5 | 1.6 | 2.8 | 27.4 |
| 7. | *Mureanosox.* | 2.7 | 5.0 | 3.8 | 14.3 | 3.7 | 1.8 | 31.3 |

N. B.:—The total catches of all fish in all sections: 715.3 tons.

*PRINTED BY*
KASAI SHUPPAN INSATSUSHA
MINATO-KU, TOKYO, JAPAN
東京都港區芝南佐久間町1－53
笠井出版印刷社印行